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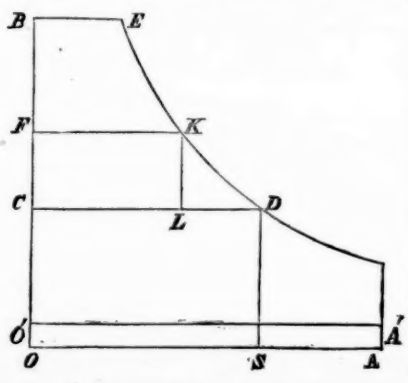
ON COMPOUND ENGINES.

(*Continued from page 7.*)

In compound engines with a receiver there arise two independent causes of loss, as the steam passes from one cylinder to the other. In the first place, the forward pressure in the large cylinder is less than the backward pressure in the small, on account of the resistance of the passages, etc. This loss can be more conveniently allowed for in practice than calculated theoretically, and has accordingly been neglected in the diagrams.

The second loss arises whenever the final pressure in the small cylinder is less than the pressure in the receiver at that time. Let a volume of steam contained in the high-pressure cylinder at the end of the stroke be represented by F K. When the exhaust takes place, let the pressure O F be reduced to O C. Then C D will be the back pressure in A, and the forward in C; and the work done in A will be the area B L. If the steam had been gradually expanded to the volume C D the work done would have been the area B D. The work done in the low-pressure cylinder would have been the same in each case; consequently K L D, the difference of these two areas, will under the first conditions be a loss, which may be termed a loss from sudden expansion.



The accurate value of K L can be found from the previous formulæ, but an approximate result will be obtained by considering it as the difference between the final pressure in A and the forward pressure at the point of cut-off in C. If K D be taken as a straight line, the loss becomes

$$\frac{1}{2}\,\frac{C\,P}{r}\left(\frac{C}{A}-q\right)\left(\frac{1}{q}-\frac{A}{C}\right).$$

The area of the whole figure, or possible work of both engines, is

$$\frac{C\,P}{r}\,(1+\log r).$$

The proportion of loss to possible work is

$$\frac{\left(\frac{C}{A}-q\right)\left(\frac{1}{q}-\frac{A}{C}\right)}{2\,(1+\log r)}$$

The percentage of this loss is given in the table at the end of this article for different proportions of cylinders and values of q. The results were obtained by actual measurement of the diagrams.

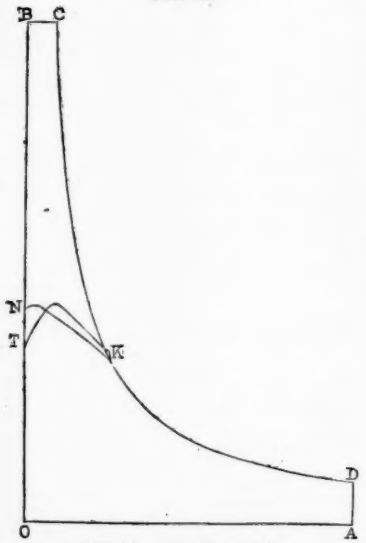
It will be noticed that when $q = \frac{C}{A}$ the loss vanishes; the back pressure is then the same as the forward in A, and consequently no drop occurs. Figs. 10 and 12 correspond to this condition.

It will be seen from the tables that the loss may reach as much as 25 per cent., and that in actual practice with the late cut-off usually adopted it would range from 5 to 10 per cent.

The work thus lost will not of course be dissipated; it will remain as heat in the receiver, will superheat the steam there, and prevent its liquefaction in the low-pressure cylinder. This may account for the fact that compound engines do sometimes work at high rates of expansion without jacketing and without experiencing much trouble from condensation in the cylinders. But at the same time it is highly improbable that all the work lost is utilized in this way, and certainly with jacketed engines it would be unnecessary.

If the only point to be considered were the economy of the steam, it would seem desirable to employ that ratio of cut-off which, as in Figs. 10 and 12, obviates this

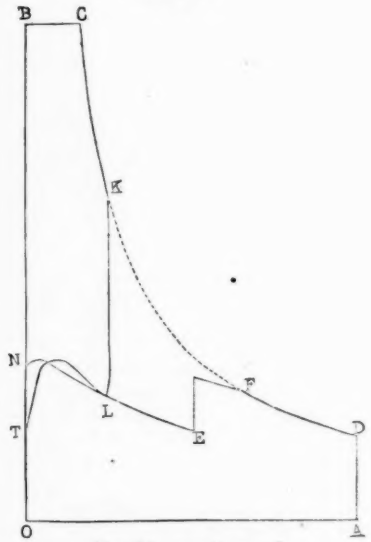
FIG. 10.



C = 4A $r = 12$ $q = 4$

loss. But it is also important for the efficiency of the engine that the work done in the two cylinders should be divided in some fixed proportion. It is generally considered that the best results are attained when this proportion is unity.

FIG. 11.



C = 4A $r = 6$ $q = \frac{3}{4}$

It is obvious that the values of q, which insure no loss by sudden expansion, will not in general divide the work evenly. This disproportion of work is absurdly evident in Fig. 12. But, if required, a proportion of cylinders can easily be found which will satisfy both conditions.

Let $$\frac{C}{A} = x.$$

Then the expansion in

$$A = \frac{r}{x},$$

and when there is no drop

$$q = x.$$

The back pressure

$$= \frac{P\,q}{r} = \frac{P\,x}{r}.$$

The work done in the high-pressure cylinder

$$= A\,P \left\{ \frac{1 + \log \frac{r}{x}}{\frac{r}{x}} - \frac{x}{r} \right\}.$$

The total work

$$= C P \frac{(1 + \log r)}{r}.$$

If the work has to be twice that developed in each cylinder, we have by reduction

$$\log. x = \frac{\log r - 1}{2}.$$

(The logarithms used are in every case hyperbolic.)

So also in the same way we can obtain a proportion of cylinders which shall give no loss by expansion, and which shall divide the work in any required proportion.

To obtain these results geometrically, it is only necessary to construct the curve of total expansion, where O A (on the preceding page) represents as usual the volume of the large cylinder, and to draw any line C D dividing the figure into two areas in the required proportion. Then $\frac{O A}{O S}$ will represent both the proportion of the cylinders and the value of q. But this result will not be strictly correct, as it makes no allowance for the loss in the large cylinder by imperfect vacuum and by resistance, etc., between the engines, so that the line O A must be replaced by O′ A′, where O O′ represents the probable sum of these losses. So, too, in the algebraical method the exact formula becomes

$$\log x = \frac{\log r - 1}{2} - \frac{p r}{P},$$

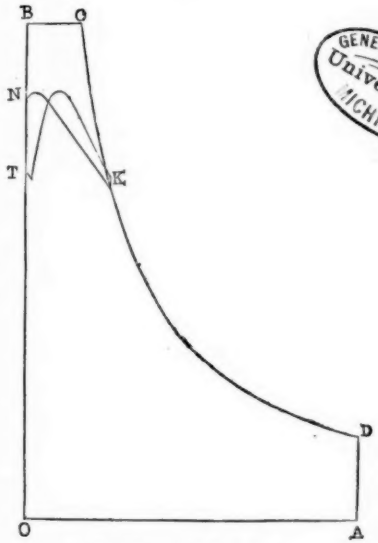
where

p = loss in pounds per square inch.

When the ratio of the cylinders has been decided, a value of q can be found by the same method which will divide the work in any required proportion, but this value of q may or may not entail a large loss by sudden expansion. It is a more difficult matter to decide satisfactorily upon what is the best proportion to divide the work. In practice the horse power of the low-pressure engine is generally only about two-thirds of that in the high, while at the same time it is usually admitted that they should be about equal; but even for the latter statement there seems no valid argument. There are two points to be considered: First, to reduce the maximum strain on the moving parts separately associated to each engine —viz., the piston and rods, crosshead, etc.; and secondly to maintain the twisting moment on the shafting as uniform as possible. The first condition will evidently be satisfied when the maximum, or what is generally the same thing, initial pressure is equal in each engine.

If the point of cut-off were the same in each cylinder this would occur when the work was evenly divided; but this is rarely the case, and when otherwise, the cylinder, which has the greater ratio of expansion, should develop the less power.

FIG. 12.



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$C = 4A \quad r = 6 \quad q = 4$

Equating the initial pressures, we have, when q is greater than 2, by formula 14, neglecting the small term l' A:

$$C \frac{\left(\frac{P q}{r} B + \frac{P C}{r}\right)}{B + \frac{A}{2}} - C p = A \left(P - \frac{P q}{r}\right)$$

when q is less than 2

$$C \left(\frac{P q}{r} - p\right) = A \left(P - \frac{P q}{r}\right).$$

In these equations, q is the only unknown, and can consequently be readily determined. If q be found to be a little more or less than 2, the first equation will give the more trustworthy result, as the second is only approximate, and always gives a value slightly in excess.

If p be taken as $\frac{P}{15}$ we find,

where $r = 12$, and

$\frac{C}{A}$ . . 4 . . 3 . . 2, respectively,
q becomes 1.8 . . 3 . . 4.6,

where $r = 6$,

q becomes 1.5 . . 1.8 . . 2.

It may be seen from the table at the end of the article that the distribution of horse-power between the two engines is almost entirely independent of the ratio of the cylinders. That for a given value of q the work done in the high-pressure cylinder will be almost exactly the same, whether that cylinder be a half or a quarter the volume of the low-pressure one. But the initial strain in A is A $\left(P = \frac{P\,q}{r}\right)$ and varies, for the same work done, directly as A. Therefore the smaller the volume of A the less is the initial strain, assuming as before that A is greater than $\frac{C}{r}$. In a pair of simple engines of the same total horse-power and ratio of expansion, the volume of each cylinder will be $\frac{C}{2}$ and the initial strain $\frac{P\,C}{2}$. This will always be greater than the corresponding effort in the small cylinder of the compound engine if that small cylinder be more than half the volume of the large.

We come now to the determination of the conditions which shall give the most uniform crank effort, and this determination, though perhaps more important, is at the same time more complicated.*

The method generally adopted to obtain the moment in the crank-shaft is illustrated in Figs. 13 and 14. The horizontal line A B, which represents the path of the crank-pin, is divided into equal distances, and the product of the pressures at corresponding positions of the piston and the sines of the angles passed through by the crank are set up as ordinates. If the connecting rod be infinite, these ordinates will be the twisting moments in the shaft. As one engine is 90 deg. in advance of the other, the curve D K B of one engine must start from the middle point of the curve A F C of the other. The sum of the ordinates at the same points will give the combined curve F S K L. The more nearly the greatest ordinate approaches the mean line M N, the more uniform will be the motion, The best result will evidently be given. not necessarily when the work is the same in each engine, but when the greatest ordinate K O equals the greatest ordinate L T. If the cut-off in each engine were the same, this would be equivalent to equating the horse power; but if otherwise, the engine which has the earlier cut-off should also develop less power. This is exemplified in Figs. 13 and 14. The upper one corresponds to the case when $r=12$, $\frac{C}{A} = 2$, $q=2$; the work done is in the proportion of 11 in the high-pressure to 10 in the low; the greatest moment is more than twice the mean. It is plain that the work done in the low pressure should be very much increased relatively to the high.

In the lower figure $r = 6$, $\frac{C}{A} = 2$, $q = 2$. The low pressure area is nearly twice as great as that of the high, but the greatest moment in this case is only 1.2 times the mean.

The table at the end of this article gives the value of the ratio of the greatest to the mean ordinate for various proportions of cylinders. The ordinates were calculated for every 10 deg. of the crank circle, and on the assumption that the connecting rod was infinite. Although the results given will consequently be too small in each case, they will still hold for the purposes of comparison. On examining the table, it will be admitted that it is of the utmost importance to have some idea, before designing the shafting of an engine, of the ratio of the maximum twisting moment to the mean. Although under the most favorable circumstances this ratio may be brought very closely to unity, yet with proportions of cylinders and points of cut-off not unfrequently employed, a stress may be thrown on the shafting of more than half as great again as the mean intensity, and not impossibly of more than twice that mean. This is of the more importance when we remember that the formulæ for strength of propeller shafting in general use allow for very little more than the mean twisting moment.

It is impossible to lay down any fixed proportion in which to divide the work between the two engines so as to obtain the most uniform crank effort; the proportion will vary for every different ratio of the cylinders themselves and for every degree of total expansion. But by the following con-

* The subject of crank effort is dealt with very exhaustively by M. Armengaud, in his "Traite Theorique et Pratique des Moteurs a Vapeur."

siderations it is possible to find a value of q in terms of the other known quantities, which will accomplish the desired result. In every half circle of the crank there are always two points of maximum torsion, one corresponding to the greatest ordinate in the low-pressure curve, the other to that in the high-pressure curve. These points will

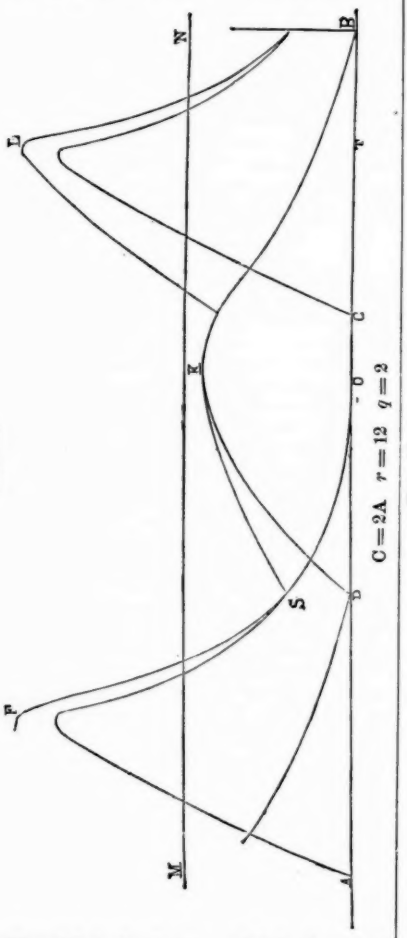

Fig. 13.

be K and L in the figure, and it is clear that the ratio of the maximum to mean stress is least when these ordinates are equal. As the combined ordinates are derived partly from each engine, any expression involving them becomes very complicated. But an approximate result may be obtained by equating the greatest ordinate due to each curve singly. In the high-pressure engine the greatest twisting moment occurs either at the point of cut-off or at half-stroke, according as this cut-off takes place before or after half stroke.

In the low-pressure engine, if the cut-off occurs after half-stroke, the general expression for the twisting moment will be by formula (14).

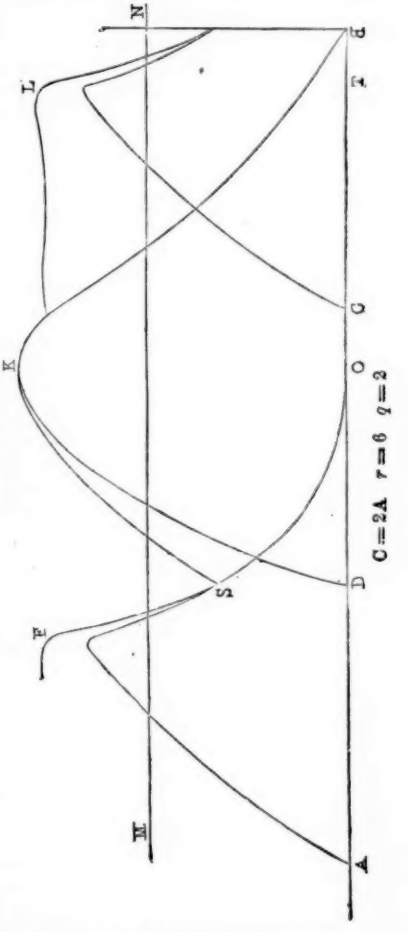

Fig. 14.

$$\frac{CP\frac{q}{r}(B+r'A)+\frac{PC^2}{r}}{B+\frac{\text{vers }\theta}{2}C+\frac{1-\sin\theta}{2}A}\sin\theta. \quad -$$

By the differential calculus, this will

be found to have a maximum value, when

$$\cos\theta = \frac{C}{2B + C + A}.$$

Substituting this value of θ, and equating to the greatest moment in the high-pressure engine, a value of q is obtained. Let q_1 be the ratio of expansion in the high-pressure cylinder, ϕ the angle passed through by that crank. Then

$$\sin\phi = \frac{2\sqrt{q_1 - 1}}{q_1},$$

and neglecting the small term l' A,

$$A\left\{P - \frac{Pq}{r}\right\}\frac{2\sqrt{q_1 - 1}}{q_1} = \frac{\frac{CP}{r}\left\{q\,B + C\right\}\sin\theta}{B + \frac{C\,\mathrm{vers}\,\theta}{2} + A\,\frac{1 - \sin\theta}{2}} - C\sin\theta.$$

When q is less than 2, the greatest twisting moment will occur in general, and always approximately, at the middle of the stroke; the right-hand side of the equation then becomes

$$C\left(\frac{P\,q}{r} - p\right).$$

When the connecting rod is not considered infinite, let b be its length, a that of the crank, ψ the angle the connecting-rod at any moment makes with the direction of motion of the piston

$$\text{Then } \frac{\sin\psi}{\sin\theta} = \frac{a}{b},$$

and the twisting moment = pressure on the piston $\times \frac{a\sin(\theta + \psi)}{\cos\psi}$ and the formulæ must be modified accordingly.

The results in the table were calculated for an infinite connecting-rod neglecting the loss between the cylinders, and allowing $\frac{P}{30}$ as the back pressure in the large cylinder due to an imperfect vacuum.

With the same assumptions we obtain from the formulæ that,
where $r = 12$ and

$\frac{C}{A}$	4	. . .	3	. . .	2,
q becomes	2.5	. . .	3.19	. . .	3.9,

where $r = 6$,

q becomes .	1.3	. . .	1.6	. . .	2.

These values will be found to agree with those indicated by the table, and are a proof that the formula is sufficiently approximate for practical purposes. They do not differ very materially from those which give the least straining action on the piston, but in some cases they may involve a considerable loss by sudden expansion. In general, however, a ratio of cylinders may be found for any required total expansion which will fairly satisfy all three conditions. As for example, $\frac{C}{A} = 3$ when $r = 12$, and $\frac{C}{A} = 2$ when $r = 6$. It may be noticed that when the expansion is high and the cylinders not widely different in size, the value of q to obtain the most uniform crank effort and least strain on the piston will involve a back pressure greater than the forward at the end of the high-pressure stroke. Such a case occurs when $\frac{C}{A} = 2$, and $r = 12$, and it may be doubted whether, even with those proportions, a uniform crank effort should not be attained, although one engine would have to drag the other for part of the stroke.

In conclusion, we have, in designing the arrangements of a compound engine, to attend to the following considerations:—When the horse-power to be developed, and the total ratio of expansion to be employed are settled, the size of the large cylinder is also known. In determining the ratio of the large to the small cylinder, it is to be remembered that the greater that ratio the less is the total weight, prime cost, and space occupied, and the less also is the maximum strain on the piston, cross-head, etc. In determining the cut-off in the large cylinder there are three points to be considered: The loss of work by sudden expansion, which disappears when $q = \frac{C}{a}$, and is smaller as this value is approached; the least strain on the piston; and the most uniform crank effort. The values of q to obtain the best results in each of these directions can be readily obtained from the formulæ given in the article, but as in general these values will not coincide, a compromise must be made, according to the wishes of the designer.

It will in many cases be necessary to fit an expansion-valve to the low-pressure cylinder, but we shall then have in our power the means of adjusting the work developed, in any ratio required between the two cylinders when working at any degree

of total expansion. It would seem desirable under these circumstances to supply those who are to control the engines with a table showing the cut-off in the low pressure cylinder which will best suit the various grades of expansion in the high.

To compare the general results of a compound engine with a receiver with those given by a pair of simple engines, it will be seen that the former has to labor from an unavoidable loss by resistance of passages between the cylinders, and in many cases from a loss (which, however, may be avoided) from sudden expansion. That the room occupied is greater, and that the whole weight of the small cylinder is extra. But, on the other hand, the maximum strain on the piston will be less, and consequently the framing and moving parts may be lighter. The crank effort will, if well arranged, be more uniform, though, if no care be bestowed upon the division of work, it may very possibly be even worse than in a simple engine.

Total Expansion, 12.					Total Expansion, 6.		
Ratio of cylinder.	Cut-off large cylinder.	Percentage of loss of work.	Ratio of work in A, to work in C.	Maximum to mean crank effort.	Percentage of loss.	Ratio of work in A, to work in C.	Ratio of crank effort.
Simple engines.				1.75			1.35
4	1	22.6	4.0	1.74	26.0	1.7	1.24
4	3/2	14	1.57	1.57	13.3	.83	1.22
4	2	9	1 44	1.4	10.0	.55	1.26
4	2	5	.68	1.25	5.0	.32	1.5
4	3	2.5	.58	1.38	1.6	.18	1.7
4	4	0	39	1.6	0	.098	2 0
3	1	15	3 6	1.94	16	1.7	1.33
3	3/2	6	1.63	1.72	7 6	1 0	1.17
3	2	3.5	1.09	1 51	4.0	.63	1.33
3	2	2.5	.9	1 31	1 6	.48	1.39
3	3	0	.62	1.2	0.0	.27	1 55
2½	1	7.5	3.3	1.98	12	1.76	1.6
2½	3/2	5	1.64	1.68	5.0	.83	1.27
2½	2	1	1.0	1.58	1.7	.62	1 21
2½	2	5	.9	1.56	.8	.52	1.33
2½	3	0	.57	1.49	0.0	.32	1 30
2	1	6	3.2	2.42	7 6	1.9	1.73
2	3/2	5	1.6	2 17	1.8	.9	1 42
2	2	0	1.1	2.06	0.0	.57	1.21

It may be urged against the conclusions of this paper, and more especially against the numerical results, that they are essentially but approximate, and in some cases involve assumptions which may require modification in practice. But at the same time we think the errors induced in this way will not be very large; and that the true solution of the problem—viz., of the conditions of maximum efficiency of a compound engine—must lie in the direction in which we have endeavored to trace it out.

THE IRONWORKS OF THE PHARAOHS.

By CHAS. W. VINCENT.

From "Iron."

Copper and its alloys were held in high favor with the earliest civilized nations of the world long after the discovery of iron, and even after it began to be really utilized —of this there can be no doubt. The bronze age in every part of the old world preceded the iron age. The change was not however, a rapid one; the replacement of copper by iron was gradual, and in this country did not take place for many centuries, perhaps decades, after its introduction and general use in the East—the birthplace of material civilization, as well as the starting-point from whence has swept over the world, as with a mighty wave, those aspirations for better and more lofty things, from

which will proceed all that is moral, intellectual, or noble in man as he now is, in whatever part of the globe, or under whatever conditions of life, he may be.

I think, however, that we are apt to date the use of iron at too late a period; we are too ready to take the tardy civilization of the north of Europe as being the origin of all our present knowledge, and to ignore the fact that in the East and South were nations possessing, thousands of years before that time, an intellectual vigor, it may be, even in excess of the average of our age. The comparative endurance of the metals iron and copper may also have helped this mistake. As soon as it came into general use iron would be much less costly than copper, and, consequently, would not be preserved with so much care, so that, being very readily oxidizable, few implements or weapons can remain to us, except where they have been kept from access of air. Hence the comparative abundance of copper and bronze articles, and the paucity of iron, may have been much misconstrued. Stone chisels, tools for wood cutting of all kinds, knives, etc., were made of an alloy of copper and tin.

On the testimony of Homer, Thrasyllus, and others, iron was in use long before the Trojan war. In the Bible, Tubal Cain is named as "the instructor of every artificer in brass and iron;" but, nevertheless, no mention is made elsewhere of iron weapons or implements till after the exodus. Iron rings have also been frequently discovered in Egyptian tombs. Moses compares Egypt to an iron furnace (Deut. iv. 20), and Job speaks of smelting processes (xxviii. 2): "Iron is taken out of the earth, and brass is molten out of the stone." From the foregoing it appears, in spite of the arguments of the difficulty of smelting it, and rendering it malleable, adduced against the early use of this metal, that it was largely in use at a very early period.

In 1822 Mr. Burton discovered an iron mine at Hammami, between the Nile and the Red Sea, which had been worked by the Egyptians. Kenrick states that in the sepulchres of Thebes he has remarked butchers sharpening their knives on a round bar of metal attached to their aprons. The blue color of the blades, and the distinction between the bronze and steel weapons in the tomb of Rameses III.; one being painted red and the other blue, leaves no doubt but that the Egyptians of an early Pharaohnic age were acquainted with the use of iron.

The minuteness and finish with which the hieroglyphics are sculptured on obelisks, and other granitic monuments, may also be adduced as strong arguments that the workmen must have been possessed of steel chisels, quite as finely tempered as any we at present can manufacture.

The amount of metallurgical skill the first smelters possessed was not very great; probably much more pains were bestowed on the manipulation of the metal after they had obtained it in a crude state, than upon getting a fair return from the ore smelted. As, in this country at the beginning of the present century, the waste heaps at the mouth of lead mines were eagerly reworked to obtain the lead and silver which our ancestors had failed to extract; so the Egyptian mines of silver, gold, and iron, may probably, ere long, be hunted for, and the *débris* from them prove a treasure trove to those who are so fortunate as to hit upon them.

An intimation that something of this kind is even now being done was made at a recent meeting of the Society of Antiquaries. Mr. Hartland described his visit to the wells of Moses by the Red Sea, the Wilderness of Sin, and the monotonous three days' march across the sandy desert, under a vertical sun, to the delicious palm-tree groves of Wady Gherundel and the defiles leading to Sinai.

An English gentleman, whose name is withheld, travelling in these parts, was struck with the small blue stones he discovered in the dried up watercourses, which in the rainy season convey the thousand streams that hurry to the sea, and, having the curiosity, to bring some home, he soon discovered that they were turquoises of no common order.

This determined him to make further researches. Eventually he has built a house near the junction of the Wady Kenuch, the Wady Mokatteb, or the Written Valley, and the Wady Megham. Here, aided by the friendly tribes he has taken into his pay, he has discovered the old turquoise mines of the ancient Egyptians, the rocks that they worked for the stones, the very tools they used, and their polishing and grinding places.

Being a man of much energy, he has brought to bear upon this fortunate discovery, the advanced knowledge of our times,

and he is obtaining and sending over to this country some of the finest specimens of turquoises that exist.

In such a lonely spot, he naturally has not confined his attention to this subject only, but has traced out the system of fortifications by which the Pharaohs protected their works and workmen, and, what is still more wonderful, has come upon the remains of vast ironworks, so vast indeed, that many thousand people must have been employed upon them, unless the plant used was on quite as grand a scale as that of our largest furnaces in the north of England.

These works stand adjacent to the mines, on some hills at a place called Surabit-el Khadin, and were evidently conducted on the Catalan system (in the opinion of their discoverer). The ore was very imperfectly extracted—slag brought over to this country, from the immense heaps that, like mountains, are piled around, contained as much as 53 per cent of iron.

These works were commenced in very early times: each Pharaoh, as he continued them, added a large engraved stone, not unlike our tomb-stones, to state his work. It is to be hoped that rubbings of these stones may be sent to some of our skilled readers of hieroglyphics, since much valuable historical information respecting the Egyptian metallurgy may have been by them preserved for our enlightenment, and to show how little the mind of civilized man has really developed during 3,000 years.

In the neighborhood a small temple was erected for the use of the workmen, and here also was a barrack for the soldiers who protected, or kept them in order.

This district has remained unexplored, probably on account of its being quite out of the beaten track; and in an unknown conntry there is no temptation to stray, particularly as the guides and dragomans discourage any explorations which may add to the risk of the journey. It is, however, much to be desired, that now that attention is directed to the locality, and moreover, since the thorough investigation of its sites is likely to prove exceeding profitable, that the enterprise and desire for knowledge of our scientific explorers may find help from the ready hand of some of our commercial magnets, and thus, that a past book in the world's history may, by English perseverance, be re-opened.

ON THE BLOCK SYSTEM OF WORKING RAILWAY TRAFFIC.*

From "Telegraphic Journal."

The author was afraid that electricians would be disappointed at the character of the paper which he was about to read, and that those of the railway world would be affronted at the position which he took in assuming to himself the functions of a Mentor. But, in fact, the railway system of this country is as yet far removed from the summit of the engineer's ambition—a perfect working machine, though it is certainly approaching that point. While the carefully prepared statistics of the Board of Trade show that the traffic is increasing with marvellous rapidity, the average number of total accidents is stationary. In the three years ending 1849, the average number of passengers killed by causes beyond their own control was 12, being (roughly) one in four million passenger journeys made. In the year 1871 the number killed was the same, while the proportion to the passenger journeys made was one in 31 millions. We have in these statistics the most powerful evidence of improved working, and of the beneficial effect of that process of scientific thought which is the application of the lessons taught by past experience to new and different circumstances. The reports of the inspecting officers of the Board of Trade upon the accidents which occur show exactly where the shoe pinches, and favor the application of the law of average in bringing out the defects or merits or variations in railway working.

Dangerous modes of working are frequently carried on for long periods without accident, but they invariably break down at last. One railway company may use an imperfect system for many years without accident, but if 12 different companies adopt the same system, the probability is that before many months elapse something will show a defect which requires to be cured. The

*A Paper read before the Society of Telegraph Engineers by Mr. W. H. Preece.

published reports of the Board of Trade furnish experimental data from which a pure science of railway working can be formed. A careful examination of 138 accidents which were reported upon has enabled the author to summarize the causes of accidents into four heads. Those due to defective permanent way have formed 18 per cent.; those due to defective rolling stock 13 per cent.; those due to defective human machinery 41 per cent.; those due to defective signalling arrangements 28 per cent. Of these accidents 56 per cent. were the effect of collision always preventable.

Now, the question naturally arises, why should there be such a wide difference in the safety of trains travelling upon the Southern lines as compared with the Northern lines? Is it that the elements of accident are more abundant in the latter than in the former; that the traffic is more crowded; that there is a greater variation in the character of the trains; and that the speed is higher? Or is it that the systems are more lax, and that the accommodation is more defective? The author cannot answer these questions; but there is one fact strikingly evidenced on the Southern lines as compared with the Northern lines, namely, that upon the Southern lines the block system is carried out in its entirety to a greater extent than upon the northern lines. Of the 16,000 miles of railway in the United Kingdom, only about 4,000 are worked upon the much talked of block system. Now, what is the block system? It is that system by which trains are kept apart, upon the same line or rails, by a certain and invariable interval of space, instead of by an uncertain and variable interval of time. The term "block" itself is a most unfortunate one. It was introduced in the early days, through the practice of blocking or pinning over the telegraph needle in the early instruments used to work this system. The "*space* system," in opposition to the "*time* system" would have been far more appropriate. The practice under the time system is to exhibit the danger signal for five minutes, and the caution signal for five minutes more, after a train or engine has passed any station, junction, level, crossing, or siding. Trains are thus kept apart by fixed periods of five minutes, and, if the caution signal were more properly regarded, they would be kept apart by an interval of time even longer than this. The speed of a train is entirely the responsibility of the driver. Immunity from accident is dependent upon his keeping a clear look-out. If engines ran at regular and fixed speeds, if the driver could always insure a good view before him, and if the signals were near together and were properly regarded, a rigid interval of time might be maintained between following trains. But none of these elements of safety are constant. Fast expresses follow slow goods trains, now through a thick fog, and then in bright sunshine. Trains are so frequent in some places that the interval cannot be adhered to; obstructions to view arise from curves and cuttings and atmospheric causes; long lengths of line are unprotected by signals, and signals themselves are frequently neglected. Hence the time system is brimful of elements of danger, and the inexorable logic of facts has shown that the time interval is illusory, and the system unsafe. When trains are invariably kept apart by an interval of one or two miles, collision between them becomes impossible. This is the block system. This system has, very improperly, been divided into two classes—the "absolute" block and the "permissive" block. The absolute block is the block system proper. The permissive block is not a block system at all, but a system introduced by the London and North Western Railway Company at the suggestion of Mr. Edwin Clark, not to secure the safety of their trains, but to increase the capacity of their line for the transmission of their enormous and increasing traffic. It is doubtless an improvement on the time system, but it bears little affinity to the block system, and should certainly not be included in the same category. There is a very broad distinction between the block system as an abstract principle and the means of carrying out that principle. We hear of Tyler's, of Walker's, of Spangaletti's, of the needle, and of other block systems. They are *not* block systems, but simply instruments devised to carry out the electrical portion of the block principle. The carrying out of the block system means an entire rearrangement of the rules and regulations of the working traffic, a complete reorganization of the signals, the construction of fresh siding accommodation, the education of the staff, the transference of much responsibility from the drivers to the signalmen. Moreover, the working of the block system is not necessarily an electrical question. If the sections of the line be very short it can

be worked by mechanical or by pneumatic agency, and where the sections are long and the trains are few it can be worked by a staff. On busy occasions, when the trains are numerous, it is quite possible to work the block by ocular agency, by merely planting men within sight of each other to regulate the trains by flags and other means. The time system having been proved to be inefficient, and the block system having been shown to be the safer principle, how is it that the adoption of the block system in this country has been so slow? People as a rule are very sceptical of any new invention until it has been practically established for a long period, and particularly so when it is based upon principles which are not understood. It took the public a very long time to get used to railways, and it took railway authorities a much longer time to get used to the telegraph. Even now the telegraph is looked upon as an expensive auxiliary, bringing in no returns; or, at least, this was the case before the transfer to the Government. The accidents it has prevented and the lives it has saved are unknown. It is the last thing thought of in the construction of a line; it is the very first thing flown to in moments of danger and difficulty. But its principles are not understood; and the application of electricity to signalling purposes is still less apprehended. On the London and South-Western, the first outlay in the construction of the block was £125 per mile. The annual cost of maintenance is £60 a mile. On the London, Chatham, and Dover, the first cost was £174 a mile; the annual maintenance £60 a mile. On the Midland line the annual cost is between £30 and £40 a mile on the main line between London and Bedford according to returns furnished to the Board of Trade, but this sum probably referred only to the electrical portion of the system. The South-Western figures, probably, more nearly represent the total cost of maintenance. The electrical appliances form but a small item of the total cost of the block system, the expense being chiefly due to the signal boxes, interlocking apparatus, and other accessories. But in addition to the question of cost which has delayed its introduction, there is a certain amount of prejudice against its working. It is said to introduce delay, and to be objectionable because it removes the responsibility from the driver to the signalman. Experience had shown that, under proper regulations, there is not only an absence of delay, but absolute expedition in working, with the block system, and that the capacity of a line for the conveyance of trains is largely increased thereby. And, as regards the responsibility of the driver, this had, if anything, been increased, for the correct working of the block depends essentially upon the driver paying proper regard to the signals. But, in addition to this, the block system has instilled into the driver an amount of confidence which he never felt before, and checked that daring recklessness that was at one time so prevalent. Thus prejudice, cost, and indifference, have led to the neglect of the block system. These objections are, however, rapidly dying out, and most of our great railway companies are now largely extending the block. In the external visual signals uniformity should be secured. The author is far from advocating the block system as the cure for every evil. We know well that where we are dependent upon human agency mistakes will arise; and various defects in connection with the permanent way and rolling stock might be a cause of accident. But the author contends that a compulsory block system would cause other improvements to follow in its wake.

The second paper, on the same subject, was read by Major Mallock. The author was lately ordered by the Government of India to report on the use of the telegraph in connection with railways in England, and the paper contained some of the results which he had arrived at in pursuance of that order The block system, as used in England, is chiefly applied to double lines, and may be distinguished by the general name of the non-following block, in contradistinction to the non-meeting block which is necessary on single lines. There are various methods of carrying out the block system, any one of which, looked at by itself, is apparently perfect, but to choose between them it is necessary to know what is really required. No rules on the subject have been issued by the Board of Trade. There are seven main classes of instruments now used with the block system. There are also variations of them, but these all depend on the main classes. There is, first, a double needle instrument, combining a bell, introduced by Mr. Edwin Clark on the London and North-Western Railway, in 1854; second, electro-magnetic semaphores

combined with bells, introduced by Mr. Preece in 1862; third, variations of Clark's needles and bells, introduced by Spangoletti in 1862; fourth, the working of bells alone, introduced by Walker on the South-Western Railway in 1861; fifth, an electro-magnetic semaphore combined with bells, introduced by Mr. Walker in 1866; sixth, two indices combined with a bell, introduced by Tyler in 1869; and seventh, a modification, introduced in 1872, of Preece's original intrument of 1866. The first three of these instruments are usually called three-wire systems, and are worked by a permanent current. They require one wire for each line of rails, *plus* one wire for the bell. The last four are called one-wire systems, and are worked by a temporary current. A needle instrument of any sort permits of talking, and is otherwise dangerous. At first sight needle instruments seem so cheap and so easy to understand and repair, that a person not acquainted with the subject would be apt to prefer them, but there are in connection with them certain imperfections and dangers. The theory of working them is, that a constant positive current kept on the line by the commutator being pinned over will show the line blocked, whilst a negative current shows the line clear, or *vice versa*. In actual practice, however, line clear is only signalled on the train arriving, and then the needle is allowed to fall to zero, the result being that should tke needle be pinned over, and the line blocked, the needle will fall to zero. The theory is that a man ought not to consider the line clear unless he has had a call on the bell, or the needle be put over the line clear until he has answered. It will be readily seen how easy it is in practice, when a man is hurried, for him to make a mistake.

The Board of Trade inspectors have expressed their opinion that a talking instrument is most necessary, but still it is only as an adjunct to the block system. A flash of lightning may reverse the magnetism of the needle instrument so that it will show "line clear" when it is meant that the line is blocked. Of the one-wire system there is no use in contemplating Walker's bell without indices, when the introduction of the latter is a great safeguard and not much expense. In Tyler's instruments the workmanship is exceedingly good, and they are apparently the most sensitive instruments, and calculated to work the longest distances, but, like needle instruments, they are liable to have reverse signals given on them by atmospheric electricity. Also the plungers, which give the signals "Line clear" and "Train on line," are so much alike that they may be mistaken by a man in a hurry. Walker's instrument is strong, but possesses somewhat similar disadvantages. In Preece's instrument (worked by a single wire) the commutator which charges the signals "Train on line" and "Line clear" is a miniature semaphore lever, and therefore there is much less chance of mistake than with the other instruments. It also admits of interlocking, like Varley's system. In consequence of a recent addition, the signal "Line clear" cannot be given unless both sender and receiver are concerned in making it, and therefore atmospheric currents will cause no mistake. The single wire systems are generally used for the non-following block; but where there is a single line of railway, and the non-meeting block is used, the rule is that no second train goes into the same section in either direction. In India, however, they got into a complication with single lines which is not contemplated by either of these systems, namely, that the line being blocked ahead with trains going up, any number may go down it. That is the permissive block system. If absolute block is to be introduced in India, either this plan must be prohibited, or they must provide for a non-following block *plus* a non-meeting block. The author proposes to do this by two wires:—

$$A \left\{ \begin{array}{c} -B-C-D- \\ \hline \end{array} \right\} E$$

Looking upon A and E as two sidings, and B, C, D as cabins between them, the lower line of the diagram would be a non-meeting block, whilst the lines between the cabins would be a non-following block. The manager of the South-Western Railway has said that such a system combined with a train register would be perfect. The paper then gave some particulars of a conference of railway managers and others, held at Berlin on the 1st of December, 1870, with reference to the block system, and detailed a series of principles which were adopted at that conference. The author concluded with a series of twenty-four rules which he had deduced from his investigations as to the working of the block system

in England, and which coincided with the spirit of the principles laid down by the German conference, but were somewhat more comprehensive. The rules so laid down by the author consisted of a series of affirmations to the following effect:—The block system entails no loss of time, but, on the contrary, enables a far greater traffic to be carried on. It is essential to the safe working of a line. The system of the "permissive" block is most dangerous. It is of no use to establish a block system if the sections are too short for a train going at full speed to stop in, or if a slack method of working be permitted. Any station at which shunting is or may be carried on must be guarded by the block. A private code of signals between the men must not be allowed. Whatever system of block is introduced, a train register is wanted. On dangerous sections a train should report back its own arrival. Besides block instruments, talking instuments should be provided, and these must not be interposed in circuit with others, but each section must work separately. On exceptional sections the block instruments should interlock with the semaphore levers. "Line clear" should not be signalled back until the tail-board of a train is seen, lest any of the carriages should be left on the line. The line staff has proved inoperative without the assistance of the telegraph. Electric repeaters are required. The block system is as necessary with light as with heavy traffic. Where a bell code is in use, a large number of beats is liable to lead to confusion. Needle instruments which can be used for talking are objectionable as block instruments. It should be impossible to show "Line clear," unless the signalmen at both ends are concerned in making the signal. Plungers, such as those of Tyer and Walker, which may be mistaken in the hurry of working, are dangerous. At the junction of two lines the block instrument should interlock on the principle of Saxby and Farmer's interlocking semaphore levers, so that "Line clear" cannot be telegraphed to both sections at the same time. Exceedingly simple instruments are desirable. The working of the block instrument should approximate as much as possible to the working of the outside semaphore. A single-wire system, working with a temporary current, cannot be considered perfect if lightning can reverse the current or demagnetize the instrument. The receiver must not be able to alter the index of incoming signals at his station.

STRAW-BURNING LOCOMOTIVE.

From "The Engineer."

At the Vienna Exhibition an object of special attention—even thus early—upon the part of the great wheat-growers of Eastern Europe, has been the straw-burning engine of Messrs. Ransomes, Sims, and Head, of Ipswich where we have recently had the opportunity of examining the construction and seeing the working of this engine, which has but very lately been perfected after many months' study and experimental progress.

We can imagine some of our home readers sying: What can "a straw-burning engine" be, or be for? Is not straw a costly product of farm skill, scarce in certain seasons, and at all times dear and valuable as food and as bedding for our farmsteads, while as fuel, straw—why, is it not proverbially as bad, or worse, than the "thorns which crackle under the pot?" Quite true all this, of our country, and of much of the most densely-peopled and civilized parts of Europe and of North America; but far from being so as respects vast regions of semi-civilization in three out of the four great continents.

Value is but a relation. A single-barrelled rifle—such as is exported to the wild, lone lands of British North America—may be bought in London for say £4; but, arrived at Fort Pitt, and in the hands of the Hudson's Bay Company's trader, it will purchase in barter those sables or black fox furs worth in London £60 or £80. So also is it of straw. There are regions where it is so abundant, and where the surrounding circumstances and conditions are such, that it is practically valueless. Such is the fact over those measureless plains of Eastern Europe and of far Western North America, which year by year pour forth that prodigious mass of wheat which feeds so large a proportion of the peoples of Europe and of the United States. From the confines of

Russian-Poland, nearly into the heart of Russia, and reaching almost to the Black Sea and the Adriatic, and in America extending for more than six degrees of latitude, and from the Sierra Nevada to the Pacific, stretch the great wheat-growing lands of the world. The inhabitants are few in both hemispheres—a sort of agricultural nomads. The land is ploughed by bullocks, or the steam plough, and sown. The ocean of grain crop springs long there, and ripens almost unseen by human eye. The rains have saturated the soil by May or early June; dry weather sets in, the grain falls and matures in the steaming air and hot sunshine, and by August or September, if not before, the crope is ripe. Then, in Europe, out come the peasant laborers again from their *dorfs* and villages, great harvesting encampments are made here and there, the locomotive engine and the thrashing machine are set to work after the reaping machine, and the crop, led often for miles by bullock carts, is separated into grain and straw. We have no space here for details, interesting though they are, of how the grain, by means of bullock trains, or long rafts and barges, slowly finds its way down many great rivers, or over ill-roaded plains, to the great shipping ports of the Euxine and the Baltic. The straw is made into vast heaps or rude stacks, often half a mile in length, at each station. There is almost no use for it; it is too bulky for transport, there are few cattle, except those for draught, and all their wants, with those of the peasants—who are too often not very much above these in the scale of creation—are wholly insufficient for its consumption. Much of it rots, much is burnt to get rid of it, and the ashes left to spread and drift with the wind over the land. Straw is there a drug—in effect, utterly valueless; not as the straw of Quartermain or Tattersall's yards, nor even as the precious sables of Regent street were at Fort Pitt, already worth something; but the straw here is valueless, absolutely valueless—there is no use for it, it cannot be sold.

In remoter days, when all the work of these granaries of the old world was done by animal and human labor, there was no use for it as fuel– it was burnt merely to see an end of it. But with the introduction of steam culture and harvesting a change came—fuel was to be had for the engines. Coal could be had but to a limited extent; wood is not to be found often for miles upon the plains, and even brushwood is in places scarce. The idea of burning the straw as fuel to raise steam is not quite new. Some years have elapsed since it was tried, and not wholly unsuccessfully in Russia, and after a very primitive fashion. The wheels next to the fire-box of the locomotive engine were taken off; the ash-pan and fire-bars removed; a huge pit was sunk in the ground lined roughly with brule or stone, if procurable; a sort of flue funnel at one side, just the area of the interior of the fire-box of the engine, which was then placed right over this. The pit was filled with straw that was set on fire, and continually fresh straw was thrown in. The fire-box and tubes—in fact, the whole boiler and engine—became thus only a flue prolonged from over this straw furnace. Steam was gently kept up, but the waste of heat was great, the supply of straw immense, as was the labor of bringing that to the immovable point where the pit was once for all formed; and the exterior of the fire-box, indeed the whole engine, became so heated as often to be destroyed, and always rapidly injured.

So matters stood until Messrs. Ransomes and Co. turned their attention to the problem which they have now so completely solved, namely, to adapt to the ordinary locomotive engine such arrangements as should enable it to be worked steadily and to its full power with straw fuel, these arrangements being as simple as possible, as alone suited to the rude people who are to manage them, involving the least possible amount of change or addition to the ordinary engine—of such a character that the engine can be, with a very insignificant amount of charge, restored to its condition for burning coal, timber, or any other fuel. These conditions fulfilled, it is obvious that besides the abolition of the waste and technical difficulties of the pit-burning method, the great advantage would be secured that the locomotive now could follow its fuel in place of the fuel having to be brought from a distance to supply it. This problem, in all its conditions, has been most perfectly solved by Messrs. Ransomes and Co., and by means which are strikingly simple. We have examined an eight-horse (nominal) locomotive fitted for straw burning, and seen the engine for some time at work, applied to a dynamometer brake which gave a resistance requiring the steady application of twenty-horse actual power to overcome it.

The following constitutes the arrangements to adapt any ordinary engine of this class to work with straw fuel. The engine is constructed with a fire-box larger than that needed for coal fuel—in this case it is one simply 1 ft. *longer* than that for coal. The fire-bars are taken out, and three or four light wrought-iron cross bars about 4 in. apart supply their place. To the fire-door opening of the fire-box a cast iron mouthpiece is attached, carrying two or three small doors for inspection of the fire, and in and close to and beneath these, a pair of gathering, or "finger rollers," placed with axes parallel, horizontal, and transversal, are arranged. These are geared together, and can be worked at the slow speed needed either by hand, by a winch handle, or by a strap and pulley, by the engine itself. A flat shoot, or tray, much like that of a common chaff-cutting machine, extends 4 ft. or 5 ft. outwards from the rollers, in width equal nearly to their length, and open on top. Beneath the wide grille of bars described as taking the place of the fire-bars is an ash-pan, open to the front end of the engine; across the open mouth of this, and above the level of the grille, is a small tube perforated with minute holes, which discharge in little vertical threads, a small amount of water supplied from a pipe led from the ordinary feed pump of the engine. This is the entire apparatus. To start to work the fire-box is moderately filled with straw, led into it from between the finger rollers. This is ignited, and the supply of straw is kept up by continuing to turn these rollers by hand, drawing in straw, fed into the shoot by the stoker, until steam is got up. As soon as this occurs the strap pulley keeps the finger rollers going, and all that is needed is to keep up the supply of straw by the shoot. Such is the entire of the apparatus. The blast pipe in the tunnel supplies the draught in the usual way. Nothing appears to escape from the funnel but a white cloud, chiefly of watery vapor. The consumed straw does not, as might be expected, form a dense glassy slag of the silica and potass or soda contained in it naturally, but falls to the bottom of the ash-pan as a dusky flock or wig—the *pseudomorphs*, so to say, of the straws. This is little coherent, and when it accumulates the *grille* or ash-box is cleared of it by a rake or slice provided to be worked from the feeding end of the fire-box. On the occasion of our inspection, the boiler being full, the water at the temperature of the day—probably rather under 50 deg. Fahr.—the fire was kindled as described. In less than 15 min. steam began to be formed, and in about 40 min. was at 40 lbs. to 45 lbs. pressure. The time of getting up steam is, in this case, comparatively unimportant; but this rapidity is sufficient to prove that straw is a more effective fuel than commonly is supposed.

The dynamometer brake having been adjusted to the resistance due to 20-horse power, and the engine being provided with a counter, was kept at work for some time, and the general phenomena presented noticed. One man was readily able to feed in the supply of straw fuel. There was but little skill required in this operation, and a sufficient uniformity of supply was easily maintained. The entire fire-box was kept full of a ruddy glowing blaze, and the mass of flame was observed completely to fill the tubes and to reach the smoke-box.

One hundred weight (112 lbs.) of straw was then weighed out, and, from the commencement of its being fed in, was consumed in about 14 min. This may be considered as about 460 lbs. per hour, or $\frac{460}{20}$=23 lbs. per hour per horse-power. Locomotive engines of this size and make, not being provided with an expensive gear, consume of coal probably from 5 lbs. to 5½ lbs. per hour per horse-power. It would follow, therefore, that straw fuel burnt in this way is equal to from one-fifth to one-fourth its weight of coal. This is not a large result, but it is one that proves straw to be a far less despicable fuel than it has been reported or imagined. It is one, too, the use of which we think Messrs. Ransomes and Co. will yet improve upon, for their experiments so far as to the best proportionate supply of air to the fire-box, though they have secured an excellent practical result, are not ended, and no doubt can exist that any great excess of air must materially reduce the efficiency of the boiler with this fuel. It should be borne steadily in view, however, that the efficiency of straw fuel in this instance is but a secondary consideration. The straw exists in superabundance; it is valueless; the primary consideration is so to feed and burn it that it shall, without trouble or skill in management, keep up a steady supply of steam in agricultural engines; and this has been effected. The engine, as fitted for straw-burning, can be

worked with brushwood, furze, dry leaves, heather, bulrushes, reeds, etc.; and so may even find its use in other regions devoid of good fuel besides the grain plains of Europe or of America, and in the latter country may yet be destined to enable culture to be introduced into the treeless prairies of the North-West of the United States or of British America.

The straw which was used before us was of the ordinary dryness of well-saved English straw at this season; but there can be little doubt that that contained, and that all straw contains, a considerable proportion of hygrometric water; and just as the metallurgic value of wood is found greatly increased by baking or drying, so may it hereafter prove that the drying of the Russian straw in some simple form of drying sheds heated by straw may, render it a still better fuel by causing its combustion to be more rapid and at a higher temperature. But the first great step has been achieved which alone is success. It remains to ascertain and to work out what improvements in detail may be possible.

MANUFACTURE OF IRON AND STEEL BY DIRECT PROCESS.*

From "London Mining Journal."

Dr. Siemens commenced his paper by an examination into the amount of labor and the quantity of fuel required for the production of a ton of steel by the old indirect operations still practised to a small extent, and which comprise the use of blast furnaces, puddling, cementing, and crucible steel-melting furnaces. He then alluded to the Bessemer process, and to the advantage which had resulted from the introduction of cheap steel due to that process. After which he gave a description of the Siemens-Martin or Scrap process, and the Siemens or Ore process, both of which offer great advantages for the manufacture of steel of a superior quality at a low cost. Dr. Siemens then stated, that since 1866 he had been engaged in the development of a process for the manufacture of iron and steel direct from iron ore, and described the apparatus which he had from time to time designed for attaining this end.

In the pursuit of this object, Dr. Siemens, in the year 1868, constructed at Landore a rotative furnace, for the reduction of iron ore into sponge, which was attached to an open hearth steel-melting furnace, where the reduced material was converted into steel by its fusion in a bath of cast-iron; now, however, he effects the whole operation in the rotative furnace itself.

This rotative furnace is arranged as a regenerative gas furnace, in which air, intensely heated by means of regenerators, is introduced, in order to consume (immediately above the charge) the carbonic oxide, which is formed at a certain stage of the process, through the reaction of the oxygen of the ore upon the carbon mingled with it. By this means, the waste of carbonic oxide, which occurs in the blast furnace, is avoided.

As at present constructed, the rotator measures 7 ft. diameter by 8 ft. 6 in. in length, is mounted upon antifriction rollers, and is provided with gearing through which quick and slow motion can be communicated to it at will.

The rotator is closed by a swinging door at one end, is constructed partly of cast and partly of wrought iron, and is lined with bricks made from calcined bauxite, a mineral peculiarly adapted by its refractory nature to resist the action of the scoria and the high temperature required. Having been previously heated, it is then charged with about a ton and a half of iron ore, with the necessary fluxes, or admixture of other ores to form a liquid slag under the influence of heat, is thereupon set in motion, and, an intense flame being directed into it, in order to heat the ore thoroughly, carbon for deoxidation is introduced, when the ore is on the point of melting. Under these conditions, the metallic iron is soon precipitated from the molten ore, on which the slag is tapped off, and a greater speed of motion than before is given to the rotator to ball up the iron. A charge of 15 cwt. of wrought iron may be thus made in rather less than three hours with a consumption of 25 cwt. of coal to the ton of metal produced, which is about one-half of the weight of coal required for making a ton of pig iron in a blast furnace.

* Abstract of a paper read by Dr. C. William Siemens, F. R. S., at the meeting of the Iron and Steel Institute, held in London on the 30th April, 1873.

Hitherto Dr. Siemens has confined his attention chiefly to the production of steel by this process, and in this he has been thoroughly successful, producing by such means a steel of superior quality, equal to crucible steel. He is now devoting himself to the production of wrought iron, and an important feature of this process is the purity of the metal produced, notwithstanding the presence of objectionable matter in the materials employed. Thus, although coal containing on an average 8 per cent. of sulphur was used for admixture with the ores under treatment, the metal obtained, as was shown by the tables of analyses, did not contain above .013 per cent. of sulphur, when ores free from that impurity were employed, and metal made principally from Cleveland ore was obtained with at most .176 per cent. of phosphorus.

Samples of both iron and steel, giving evidence of the high quality of the metal producible, made by Messrs. Vickers & Co., Sheffield; the Sample Steel Works, Birmingham; and the Landore Steel Company, Swansea. The last-named works, which were established when the scrap and ore processes were in their infancy, are now producing 1,000 tons of steel per week.

RESISTANCE OF IRON TO STRAIN.

From "Iron."

The following brief summary of the behavior of iron under strains may not be devoid of interest and value :

Cast-iron is unsuitable for use as a tie, beause its strength is uncertain, and on account of its accommodating itself, less than malleable iron, to any cross strain. Malleable iron allows of considerable torsion, without any great diminution of its direct strength, but any twist brought on a bar of cast-iron, with a direct strain, is almost sure to result in fracture, long before the whole of its direct strength is called into action. In three experiments (two of them being by Mr. George Rennie), a mean of 8.14 tons, or about 18,000 lbs. per sq. in., broke the following bars of cast-iron :—Bar, $1\frac{1}{4}$ in. square, broke with a strain of 11.35 tons, or 7.26 tons to the square inch. Bar, $\frac{1}{4}$ in. square (cast horizontally), broke with 1,193 lbs., or 8.52 tons to the square inch. Bar, $\frac{1}{4}$ in. square (cast vertically), broke with 1,218 lbs., or 8.66 tons to the square inch. As regards the use of cast-iron to resist direct strain, there are some peculiarities; such as in the manufacture of hydrostatic presses and water-pipes, where it is noteworthy that, although it might be supposed that the strength of a cylinder, exposed to an internal pressure, is in exact proportion to its thickness, yet, practically, this is not the case; and the thickness has to be increased in a greater proportion than the strain.

The following rule is given, by competent authority, to compute the thickness of such metal. Multiply the pressure per square inch by the radius of the cylinder, and dide the product by the difference between the cohesive strength of a square inch rod of the metal, and the pressure per square inch, and the result will be the required thickness. Cast-iron being most frequently used in girders, etc., its tranverse strength is a matter of great moment. Mr. Banks rested the ends of square inch bars of cast-iron on supports 3 ft. apart, and then loaded them with weights at the centre, till fracture took place. The results were as follows :—

No.	Distance of supports.	Breaking Weight.	Mean.
1	36	756	....
2	36	756	756
3	30	1008	
	Reduced to 36 in.	....	840
4	36	960	
5	36	958	
6	36	994	972
	Average of three others..	....	730
8	36	864	869
9	36	874	
10	By Mr. George Rennie...	....	897
			6) 5064
	Mean.....	....	844

Experiments on the deflection of cast-iron submitted to a transverse strain was, on two specimens of old pig-iron, each 3 ft. in length,

smooth, clean, and regular castings, the section of the bars being rectangular, depth, 0.65 in.; breadth, 1.3 in.; the supports 35 in. apart, and the load suspended in the middle. The deflections were as follows: With 60 lbs. applied, the first bar bent 0.1 in.; the second bar, 0.1 in. With 120 lbs., the first bar, 0.2 in., the second, 0.203 in. With 162 lbs., the first bar 0.265 in., the second, 0.275 in. The iron was slightly malleable, in a cold state, and yielded easily to the file. The fracture, dark grey, and with little metallic lustre. It may be taken that 162 lbs. is the greatest weight it would bear without impairing its elastic force. Another trial with Adelphi iron, of the same dimensions, showed a deflection of 0.265 in., with a weight of 162 lbs.

Cast-iron may be considered to have its elasticity destroyed with about one-third the weight that will produce fracture. It ought not, therefore, to be loaded, in permanent constructions, to more than this amount. That there is an element of strength in beams subjected to transverse strains, arising from the lateral action of the fibres or particles on each other, has been demonstrated by experiments. They show that the neutral axis must be at or above the top of the beam, or there must be some other cause for the strength of the beam when subjected to transverse strain. It being proved that the neutral axis is in the centre of a rectangular beam, and that its position is not sensibly altered by variations in the amount of strain applied, it becomes evident that if there were no other elements of strength than the resistance to direct extension and compression, the breaking weight, as computed by the well-known formula, could be readily obtained. But the weight so calculated is practically less than half the actual strength of the beam, and further experiments show that a large proportion of the strength of cast-iron, when subjected to transverse strain, is due to the lateral action, and that comparison of the relative strengths of different forms of sections, calculated on the assumption that the resistances are constant forces or governed by a constant co-efficient, must be entirely fallacious.

The following are the results of experiments on transverse strength of square and round bars of cast-iron of 1 in. sectional area. Length of bearing 60 in.:—Square bars, broken on their sides, breaking weight, 527 lbs.; cylindrical bars, breaking weight, 474 lbs.; square bars broken on their angles, breaking weight, 449 lbs.

Square and round bars about 4 in. sectional area, bearing 60 in.:—Square bars broken on their sides, 4.010 in. area, breaking weight 3,478 lbs.; cylindrical bars, 4.977 in. area, breaking weight, 4143 lbs.; Ditto, 3.717 in. area, 3132 lbs. Square bars broken on their angles, area 4.020 in., 2988 lbs. Compound sections 48 in. bearing:—

Section in form of I, sectional area 2.60, breaking weight, 4004 lbs.

Section in form of H, area 2.59, breaking weight 2569 lbs.

On computing the above by the theory referred to, the apparent resistance at the outer fibre varies from 25,271 lbs. to 53,966 lbs., while the tensile strength of the metal as obtained by experiment on direct tension averages only 18,750 lbs. This discrepancy and variation will be found to arise from the omission of the resistance consequent on the molecular disturbance accompanying curvature. A due consideration will show that this resistance is one acting in addition to the direct extension and compression—that it is evenly distributed over the surface, and consequently (within the limits of its operation) its points of action will be at the centres of gravity of the half section—that this uniform resistance is due to the lateral cohesion of the adjacent surfaces of the fibres or particles and to the elastic reaction which thus ensues between the portions of a beam irregularly strained—and that it is proportionate to, and varies with, the irregularity of strain between the fibres or particles nearest to the neutral axis and those most remote. Such are the deductions of Mr. Barlow, argued at length by him with clearness and logical force.

In trials on hollow cast-iron columns, Mr. Hodgkinson mentions a curious and important fact. Some of the pillars were unintentionally cast with one side thicker than the other, and this gave him an opportunity of observing if there was any falling off in the strength. But it would seem that a matter which would appear to destroy all confidence in a pillar, does not produce a great reduction in its stability. The probable reason, he imagines, is this, that from some general cause the thin side was always the one compressed, and, as cast iron resists compression with about six times the force that it offers to tension, the pillar seldom

gave way by the former, and bore nearly as much as if it had been of equal thickness on both sides.

The following is a table of the breaking weight per square inch of solid cast-iron columns 1 in. in diameter:—

Length of column in diameter.	10	11	12	13	14	15	16	17	20	30	40
Breaking weight in lbs. per sq. in. of section ..	74,200	70,200	66,400	62,800	59,400	56,100	53,100	50,300	42,900	26,500	15,300

The strength of malleable iron as tested by the Admiralty at Woolwich Dockyard, in the shape of chain cable, is given as under:—

Old cable 1⅛ in. sq. bars cut into pieces 2 ft. long; 73 tons 10 cwt. Another trial of similar metal, 80 tons.

Archangel square, 1½ in. bars cut into 2 ft. lengths, piled and rolled into bolts, 71 tons.

One and a-half inch old bolts found promiscuously, and piled and fagoted by hand, 71 tons 10 cwt.

English bars, 1⅛ in. (full), piled and rolled; 86 tons. Ditto 1⅛ in. (bare), 80 tons.

The mean of all the trials gave 76 tons for the strength of a double bolt of 1½ in. diameter in the cable form, which corresponds to about 21½ tons per sq. in.

Now, by the same machine, the mean strength of wrought iron per square inch was 25 tons; therefore, the strength of iron in the cable form is to that of the simple bolt in about the ratio of 43 to 50. But with stays, the strength would be very nearly equal to that of the iron in the simple bar form.

Mr. Telford caused experiments to be made on the direct cohesion of malleable iron, the results of which are recorded as follows:—

No. 1. Cylindrical bar of South Wales iron: length when put in, 2 ft. 2¾ in.; diameter, 1⅜ in. Torn asunder by 43 tons 11 cwt.

No. 2. Cylindrical bar of South Wales iron: length 2 ft. 2⅜ in.; 1½ in. diameter. Torn asunder in 34 minutes by 52 tons 15 cwt. 1 qr. 10 lbs.

No. 3. Square bar of Staffordshire iron: length, 1 ft. 5½ in.; and ¾ in. square. Began to stretch with 12 tons, and broke with 15 tons 5 cwt. 3 qrs. 4 lbs. in 9¾ minutes.

No. 4. Square bar of Staffordshire iron: length, 1 ft. 7¾ in. by 1 1-12th inch square. Began to stretch with 32 tons, and broke with 32 tons 6 cwt. 4 lbs. in 16 minutes.

No. 5. Square bar of Welsh iron, 1 in. square. Stretched ¼ in. with 18 tons, and broke with 29 tons, after stretching 2⅜ in.

No. 6. Bar of Swedish iron, 1 in. square. Began to stretch with 17 tons, and broke at a flaw at 29 tons.

No. 7. Bar of fagoted (from scrap) iron. Began to stretch at 16 tons, and broke at 29 tons.

No. 8. Bar of common Staffordshire. Began to stretch at 19 tons, and broke at 31 tons.

No. 9. Cylindrical bar of common bar iron, 2 in. in diameter. Began to stretch at 45 tons; fractured and gave way at 100 tons.

Reduced to 1 in. square, the mean strength of the above is 29 tons 5½ cwt.

Mr. Barlow has some very interesting experiments on record respecting tubular bridges and girders. He endeavored to ascertain the exact amount of load to which a bridge may be subjected without endangering its safety; or, in other words, to determine the fractional strain of its estimated powers of resistance. They show that wrought iron girders of ordinary construction are not safe when submitted to violent disturbances equivalent to one-third the weight that would break them. They, however, exhibit wonderful tenacity when subjected to the same treatment with one-quarter the load, and assuming, therefore, that an iron girder bridge will bear with this load twelve million changes without injury, it is clear it would require 328 years, at the rate of 100 changes per day, before its security was affected. It would, however, become dangerous to risk a load of one-third the breaking weight upon bridges of this description, as, according to the last experiment made, the beam broke with 313,000 changes; or a period

of eight years at the same rate as before would be sufficient to break it. He supposes it to be more than probable that the beam used might have been injured by the previous three million changes to which it had been subjected; and, assuming this to be true, as time is an element, it would then follow that the beam was progressing to deterioration, and must of necessity at some time, however remote, have terminated in a fracture. Wrough iron girders are not safe if subjected to a load equal to a tensile strain of seven tons per square inch, and are not safe if that strain is subjected to alternate changes of taking off the load and laying it on again, provided a certain amount of vibration is produced by that process, and he considers that five tons of tensile strain on the bottom of girders is an ample standard of strength.

ON RESULTS OF A RECENT INVESTIGATION INTO ANCIENT MONUMENTS AND RELICS.*

From "The Building News."

Mr. Phené divided his subject into monuments illustrative of public rites of sepulture; of private interment; those for the performance of ceremonies; and those for sacrificial worship. His investigations on the Earl of Glasgow's estates enabled him to lay before the meeting a plan and sections of a tumulus, the principal features in which were: the general construction of the mound; a radial arrangement of the tombs; a mixed species of sepulture by the same operators, and at a common date,—in short, as the result of a single ceremony; and a rude knowledge of mechanical forces, judiciously applied. The tumulus is in the Great Cumbræ, the larger of two islands east of the southern end of the Isle of Bute, in the Firth of Clyde. The tumulus is at the extreme north of the island on which it is placed,—a position probably chosen as having in an easterly direction from it a prominent conical hill, the neighborhood of such hills having been customary places for interment, and for the exercise of sepulchral and other rites. The construction is unusual, and displays labor and intent. The original surface soil was of a very dark color, and each sepulchre stood on a separate mound of bright sea-sand; each tomb was also carpeted with a complete layer of fine white quartz pebbles, which time had detached from the red sandstone conglomerate of the coast, and which still abounds on the shore of Ayrshire. The mounds of sea-sand were almost uniform in extent, and of a common level, and appeared to have been heaped over their sides all round as soon as deposited, having between them and over their slopes a thick layer of the dark-colored original surface soil, which served to retain all in their positions. The slope of the mounds was almost that taken by sand when heaped up and unmolested by other forces—about 32 deg.; and on the summit of each heap was placed a red sandstone cist, consisting of four stone slabs, which in every case retained a true vertical position. The dimensions of these cists were approximate to each other, except in one case; they are of a size common to sepulchral chambers of this class, which have the characteristic of being hardly able to contain a full-sized human body, even when doubled up and compressed. Each cist was covered with a slab of the same material, reaching considerably over the external dimensions of the wall slabs, and apparently irregularly rubbed or worked so as to discharge rain or moisture from the centre towards the edges, or else selected from an accidental tendency to this form. In one case such economy of labor was clearly shown, by the use of a water-worn slab for the cover, which possessed these general features. These slabs were all in a true horizontal position, but were so adjusted as not to rest on the vertical or wall slabs, from which their weight was discharged by an arrangement of uncemented masonry which carried them. The whole had then been heaped over with a third soil, quite distinct from the other two, the source of which was displayed by an adjoining hollow in similar soil, which on measurement was found to correspond very nearly with the cubical contents of the tumulus, and somewhat resembled it—an inverted outline of the one tolerably representing the other. The largest and most

* A paper read before the Royal Institute of British Architects by Mr. John S. Phené.

important cist was in the centre of the tumulus, and placed nearly due north and south. It contained the unburnt, and apparently uninjured, bones of a man of full stature. Due north of this cist was a small one, which contained the also unburnt and perfect bones of a youth, and a few fragments of divers pottery. The peculiarity of the masonry is its involving probably the earlist style of arrangement which led to the use of the discharging arch. And if we take this as the rudest, and an example of the more finished of the Pictish arches in the Orkneys, we shall find their almost exact counterparts in Mexico. The author said that he had met with similar methods of discharging the superincumbent weight of the cover from the lateral slabs in Argyllshire and in Roxburghshire. As illustrating private and domestic modes of sepulture, in contradistinction to evidently public and official ones, Mr. Phené next described a small tumulus on Timpendean Moor. Observing that some tufts of heather rose above the rest in something of a circular outline, he had had the vegetation removed, when a number of slight mounds, like molehills, were seen. At about a foot in depth these were found resting on blocks of granite between two and three feet in length, and nearly a foot in breadth and thickness, which were found lying as radii; they were pointing to a common centre, but at some distance from it. Within them was a flat area, of an oval form, the external part of which was also irregular; an appearance which, on removing the soil, was found to arise from a number of loose stones in a tolerably uniform position, but looking as though they had been levelled or fallen down from time. The external measurement of these in the longest direction was about 30 ft. across, the perfectly smooth area within them being about 5 ft. less. Mr. Phené had all the soil removed from the latter, and found, at about the same depth, a very perfect paving of stones, neatly placed, and having a smooth upper surface; these were laid upon a light-colored, unwrought soil, and from a few inches to nearly 2 ft. below that was the rock. On the pavement being removed in portions, a dark patch was observed in the soil, under which was charcoal, and beneath that black and decayed wood, evidently part of a stake about 4 in. in diameter, and penetrating into the earth nearly 2 ft. below the underside of the paving.

A careful examination of the still undisturbed pavement showed in several similar positions, deficiencies in the stones, beneath which were corresponding patches of charcoal surmounting the remains of decayed oaken stakes, the holes for which, in more than one case, had perforated the soft rock beneath. These holes were equidistant from each other, and showed an uniform measurement from each to the circumference of the oval. The Eildon Hills lie to the north of this monument, and by the side of the post nearest in their direction, and a foot under the pavement, was found an inverted British urn, about 10 in. high, filled with burnt human bones and charcoal, and the mouth resting on the natural rock. At the exactly opposite one was found a small whorl, or it might be an amulet, as the perforation in the centre was small. Nothing else was found here; but it would seem that this was a burial beneath the domestic hearth, or at least within the extent of the house covering. There was an assimilation in the arrangement of the outer stones to dwellings still seen in the most northern of the Hebrides; and it appeared to the author that the oaken posts would have formed the ribs, or rafters, on which a thatch would have been fixed, the distance across, between the posts, being about 20 ft. Similar buildings are referred to by Professor Wilson, in his "Prehistoric Annals of Scotland," as being found near Loch Etive, in Argyllshire; but it does not appear that these were searched below the circular paved floor for sepulchral or other relics, though the remains of the oaken stakes were discovered. Of the class of monuments which seemed to be ceremonial, Mr. Phené described a monument of remarkable dimensions and design, on the Duke of Argyll's estate near Inverary. The major portion of this great monument had been covered with a tumulus, the earth forming which still remained in large quantities where the heavy but disturbed stonework once forming the covering of the chambers lay strewn about, though that more readily reached had been spread on the rather thin soil of an arable field in which the monument stands. The great entrance was obviously external, from the pent-house form of the large granite slab over the northern chamber, the section of which is almost in exact agreement with that of the large terminal stone at the south end of the tumulus. The

author said he called this the great entrance, as it had in front of it a much narrower chamber or doorway, against which was rolled a huge rounded stone. The width of this entrance approximated to several openings found in the obstructing stone work, which had divided the great way into a series of chambers, one of which obstructions separated the first and second chambers, situated at the northern end of the tumulus. At the south end of this second chamber there certainly appears to have been a permanent barrier, but, on excavating down to the foundations, the author saw reason to believe that this had either merely covered a secret mode of transit, or that some alteration had taken place at the time of the central and adjoining chamber having been broken up, as it evidently had been, probably by treasure-searchers. This central chamber was similarly secured by a solid barrier at the south end, though no doubt there was here also a concealed channel of communication, which, not having been discovered by the treasure-seekers, was probably the cause of the destruction of the side walls of this chamber, the east and west walls of it being only traceable by the slabs which had formed them lying near at hand; and as amongst these stones were others which were somewhat thin, as compared with those agreeing with the lateral stones still in position, these thinner slabs may have formed a domed roof to this chamber, as the position is that in which we find the central and domed chamber in the three-chambered tumulus, opened the same year by Dr. R. Angus Smith, in the same county, and which is also the position of the domed chambers at Lough Crew, and in the Boyne tumuli. In conclusion, Mr. Phené glanced at the historical evidence in favor of sacrificial worship in Britain.

MULLER'S ROPE RAILWAY.*

From the "Mining Journal."

The late enormous demand for minerals for iron-making has caused active search to be made in districts hitherto unexplored, and in many cases valuable discoveries have been rendered nugatory by the heavy cost incurred in carting the material to the nearest railway or shipping port. Ireland, Wales, Cornwall, and many parts of Scotland have many valuable districts lying unworked for want of a system of this kind, and I trust the adoption of this patent will be the means of developing these and many other districts. The use of a rope for transporting loads extends back over a large period of time, and has been used to some considerable extent, but in a very primitive manner, in Holland, India, and Italy. At the present time there are three systems in use, all of which have been practically applied, and each differing from the other in the form of construction. The first and most primitive of these systems consists of two parallel and tightly-stretched ropes, securely anchored at each end, and each rope serving as a single line of railway; on these ropes run roller frames, or monkey carriages, the tubs being fastened to and suspended from them. To these carriages are fastened a light rope, running around a pulley at the highest end of the line, the loaded car descending by its own gravity on one rope, and pulling up the empty car on the other; this system is used to some extent in France, and in some cases the ropes are stretched across a clear space, without supports, of 400 and 500 ft. In the year 1870 Mr. Hackney employed this system very effectually in removing the soil from the excavation at the extension of the Landore Siemens' Steel Works. In this case the span was 165 ft.; the speed run is about eight miles per hour, and the number of wagons sent across daily being about 300, each carrying from 10 to 12 cwt. of soil. The second system is known as Hodgson's, and consists of an endless rope, running on rollers, and supported at interwalls by iron or wood posts. The rope is driven by a motor fixed at one end of the line, the requisite friction for moving the rope being obtained by the use of Fowler's clip pulley. At intervals, suspended from the rope, are specially constructed boxes, so arranged as to maintain the centre of gravity immediately under the running rope; the full boxes pass along on one side of the line, the empty ones returning on the other. The third system is Muller's rope traject, which

* A paper read before the Iron and Steel Instute by Mr. H. M. Morrison.

is the subject of this paper. It has been invented by Mr. Muller, the director of Sigl's extensive engineering works at Vienna. Rope railways, constructed on the principle of the two first systems mentioned, require as a special condition that the material to be transported shall be carried in boxes or tubs made suitable either for travelling on or being fixed to the ropes; this forms an expensive feature in the arrangement, looking at the time occupied in loading and unloading, the risk of breakage (especially in coal), the extra cost thus incurred, as well as the cost of the additional carrying plant so required. In Muller's system this is obviated, as the tubs or trams in use at the coal or ironstone mine can be so arranged as to pass direct from the mine on to the ropes, and so pass to their destination without any delay or extra cost in unloading. The system is also admirably adapted to act as a feeder, or as a means of communication between narrow-gauge railways, whose termini are intercepted by precipices, valleys, water, etc. The simplicity, cheapness, as well as the capability of rapid construction of this tramway render it especially suitable for mountain purposes, because expensive bridges, tunnels, and heavy earthworks are rendered superfluous, as the traject, being able to overcome an ascent of one in six, can pass over the mountains in a direct line. Inundated land and broad lakes can also be passed over, and when the depth of the latter prevents the fixing of supports in the bottom, they could be fastened to anchored flats, with spans between each flat of at least 400 ft. This rope tramway can be used advantageously for factories situate at outlying distances from the railway communication, to transport the raw and finished materials to and from the works, as suitable cars of any description could be arranged to travel on the rope. No system is better adapted than this for carrying beet-root, sugar, coffee, rice, or any other kind of plantation produce. Upon the upper ropes of this tramway trees of any length can be carried by placing them upon notched cross-beams, which drop down upon the ramparts after having passed over the end pulleys, and the timber remains in a secure position, or suitable carriages can be arranged to receive them; the carrying cross-beams may be returned on the bottom line of ropes. Light cord lines constructed on this system may be applied to carrying letters and parcels at a speed averaging 10 miles per hour. The traject may also be used as a passenger line, and its safety has already been proved in actual practice. In 1870, shortly after the completion of the patent, Mr. Sigl erected a short line at Vienna, running from his works to the village of Wöhring; this tramway was carried over the fortifications, houses, etc., and was used for the transporting of heavy castings, bulks of timber, and general plant required in the erection of a large mill. It was used daily by the workmen as a passenger line, and without the slightest accident. The number of cars passed over it was about 60 per hour, each carrying 8 to 14 cwt. It was critically examined by the leading engineers of Vienna, and pronounced a great success. A short line, similarly constructed, is now in use at Schaffhausen, in Switzerland; it crosses the Rhine at the Falls and has a span of about 400 ft. It is used for carrying the workmen connected with the rope transmission of the Wasserwerk Gesselschaft. Mr. Scott and myself crossed the river in the car a few weeks ago, and can bear testimony to its general efficiency. We are at the present time making arrangements to bring this tramway into use as part of the material of an invading army for the purpose of carrying provisions and army material to and from the camp to the nearest railway or water communication. The various uses to which this traject can be applied are so numerous that I should be trespassing too much on your time to name them all in this paper. I will, therefore, now proceed to explain the model and plans, which will be printed and accompany this description. In all cases the cars are carried on two parallel endless ropes, passing at the terminal points over large driving pulleys, and being supported and guided at certain distances by smaller pulleys. The distance and application of these pulleys depend upon the nature of the ground, as well as the weight to be carried, and in many instances the expense of the wood or iron carrying posts can be avoided by taking advantage of trees or rocks which may lie in the line of route. The motor, which may be a steam-engine or water-wheel, only acts at one end. The large pulleys at the driving end are both keyed on to one shaft, and are set in motion by the motor, and at the return end the large pulleys are separately bedded, and run independent of each other, each having a tightening apparatus, so as to prevent any

unequal stretching of the ropes. The ropes themselves transfer the motion to the smaller pulleys. Any load to be transported, consisting either of vehicles, basket cars, and timber, is made to rest upon the ropes, with four claws, or notches, in order to prevent oscillation of the object conveyed, and allowing it only to follow the movement of the ropes when passing over the rollers; and while two of the claws simultaneously set free the ropes, the two other claws keep the load upon the ropes by friction. The large driving and returning pulleys are lined with wood so as to increase the grip of the ropes and avoid the wear consequent upon the ropes being drawn on iron beds. The system of disengaging claws attached to the tubs, and first used, was complicated and expensive, and, although retained as part of the patent, have now been superseded. The vehicles are now fitted with claw bars, or the claws are so arranged as to fall level with the sides of the tubs when not resting on the ropes. There is an elevation and plan of wire tramway representing any length from 1 to 10 miles. Two large pulleys near to and driven by the motor are fixed on a neutral shaft, the two opposite being bedded on separate shafts, and having a tightening apparatus, and one of new and improved form has newly been added to the patent. Wooden ramparts are provided, which serve to bring the cars from the lower to the upper ropes, and *vice versa*. The upper is called the track line, and consists of an inclined plane on which the rails are laid. The lower line is deviated at that end of the traject when the vehicles arrive at the lower ropes. This line of rails is horizontal, beginning under and between the nearest grinding rollers, so that it may receive the vehicles running off from the ropes and carry them over the rope and sideways clear of the large pulleys to the travelling platform. Natural local circumstances will always decide whether a sliding platform, turn-table, or switch is most suitable for connecting the line of rails. At the other end the traject is similarly arranged, and has a slight fall toward the first carrying rollers, so that the cars pushed off the sliding platform run on to the ropes of their own account. The coupled trajects are both worked by one motor, and can be understood without further explanation. An arrangement of this kind is most suitable for long lines, because by dividing it into sections the weight of and strain on the ropes are very considerably diminished. It also enables the line to be carried around a very sharp curve, as the shafts of the driving puleys may be so bedded that the rope way at this point forms an obtuse angle. It is scarcely necessary to mention that all carriages, tubs, or vehicles of any kind can pass the junction without stopping, or without manual help of any kind, this being effected on the upper line of ropes by the momentum of the running vehicle, and on the lower line by giving the junction rails the necessary inclination. As large cars, weighing over 5 cwt. when unloaded, are difficult to push up the ramparts, the inventor has designed an arrangement which obviates the necessity of the inclined planes: he lets the loaded and unloaded cars run along a horizontal track of rails at the ends of the traject. In this case the driving pulleys are placed nearly horizontal under the scaffolding, which supports the rails and the first guiding pulleys. It is so arranged that both the ropes run parallel, and next to each other in one direction, and those coming from the return end of the traject are placed on the same level at the side of each other, and not above each other, as in the constructions previously described. It is not necessary that these terminal stations shall be on the same plane; but, according to the requirements of the position, any inclination may be given to the ropes up to one in six, which may be worked with perfect ease. As most engineers and manufacturers taking an interest in this invention will be desirous of ascertaining the cost per mile, it is necessary in giving an estimate to have a proper section of the ground to be traversed, weight, and quantity to be carried, height of the various scaffoldings required, and number of the same, as the ironwork and erection of these latter, if used frequently, play an important feature in the cost of erection. The difference between the use of steel wire-ropes and iron wire-ropes tends also to a material difference in first cost, but taking fair average conditions of erecting one English mile, inclusive of a first-class 12-horse power portable engine, but exclusive of the erection of the ramparts, about £1,000 may be taken as fair average, according to present prices of material and labor. The wire ropes are four times as long as the whole traject, and must be of the best material and workmanship, and most carefully laid. Steel wire-rope is strongly recommended as being better

adapted to withstand wear and tear, consequent upon the necessary friction. As a general rule, the supporting posts may be placed 300 ft. apart, and with steel ropes $\frac{7}{8}$ in. in diameter a load of 10 cwt. may be carried between each support, exclusive of the empty vehicle on the top ropes, and allowing 30 seconds for clearing each space, the traject would forward 50 tons per hour, or by increasing the size of the ropes, and power of the engine, a total quantity of 100 tons per hour can be obtained. The driving pulleys average from 8 to 10 ft. diameter, and are lined with willow wood. The inside guiding-rollers average from 18 to 30 in. diameter. The upright posts for supports average from 8 to 10 in. square; ordinary Swedish or Memel timber may be used.

The President observed that every ironmaster knew the cost of transport, and the large proportion which it bore to the cost of iron, and as the object of the arrangement which had been described was to lessen that cost, he was sure the meeting would accord the author of the paper their hearty thanks.

ADMIRAL PORTER'S TORPEDO BOAT.

From "The Nautical Gazette."

We promised last week a description of this new and formidable machine, the invention of Admiral Porter. This engine of destruction is composed of a series of watertight compartments, which can be flooded or emptied at pleasure, so that the vessel can be made to sink under water until, if necessary, only a foot remains above the surface. In action nothing can be seen above the decks but an iron-plated pilot-house, a smoke-stack, and grated hatchways. The pilot-house, however, need not be occupied on such occasions, as the vessel could be steered from the engine-room below. She will be fitted up with three masts, constructed so as to disappear during an engagement; but, if found necessary, they can be run up and sail put on at a moment's notice. The sailing facilities can be available when the vessel is not in action.

When out of water the boat is shaped somewhat like a shark, the nose or ram tapering off from the bow, and projecting a distance of 40 ft. At the extreme point of this ram is situated the torpedo bar and valve, from which the deadly missiles can be discharged by electricity with terrible effect. The projection of torpedoes, however, is not confined to the forward part of the boat; she is so constructed that torpedo bars run along at both sides, so that if lying with either side toward the enemy it will be only necessary to apply the electric current and torpedoes can be projected with ease. When afloat only about 4 ft. of the vessel appears over water, and in shape, she looks perfectly oval.

The extreme length of the boat is 173 ft.; breadth of beam, 28 ft., and depth, 13 ft. The best tested charcoal iron is being used in her construction. The thickness of the plating for the sides has not yet been decided; that on the hull ranges from three-eighths to half an inch, according to the general rules for constructing iron vessels. The decks are of plated steel, from five-sixteenths to half an inch in thickness, which, it is thought, will add to the strength of the boat. The decks are arched much higher than usual, thus giving to the middle of the vessel a height greater than would appear.

The new boat is built on what is known as the English bracket principle, introduced for the first time into American shipbuilding. The peculiarity about ships constructed on this priciple is that they are virtually two distinct vessels, built one within the other, and of equal strength. Within the outside shell, three longitudinals of immense strength run the entire length of the vessels, and are connected with bars running in a horizontal direction by brackets of equal length. The whole is then covered with an iron plating of an equal thickness with the outer one, forming a distinct and perfectly water-tight bottom and sides, the different sections of which can be entered by man-hole. A passage sufficiently large to allow a man to walk in is left open between the outer and inner vessels, as they may be called, from stem to stern, so that should any accident occur to the outer plating it could be remedied from the inside. The advocates of the bracket principle claim that even should the exterior plating of a boat get damaged, and the water rush in, the vessel would

still be safe, owing to the water-tight plating constructed within.

The boat being designed solely as an engine of destruction, will not carry a larger crew than will be sufficient to work her, and during action they will remain below.

The Fowler wheel, a new propeller, will be introduced into the vessel. It has never yet been brought into use in the United Sates Navy. This propeller enables the vessel to be steered and propelled by the same wheel. It works on the eccentric principle, and allows the pitch of the blade to be altered at pleasure, so that, if necessary, a rudder could be dispensed with altogether. To provide against accident, however, a rudder will always be kept on hand.

The vessel will be supplied throughout with an improved electric apparatus, by which connection will be maintained between the engine and torpedo-rooms, pilot-house, and other portions of the ship.

Machinery of extraordinary power, and on the most approved principles, will be furnished the boat, and she will be capable of attaining as great a rate of speed when going in a backward as in a forward direction. The shock which a ram of this description, driven by powerful engines, could give to a hostile vessel would be something terrific. The great length of ram concealed under water would also enable her to strike when she, to all appearances, seemed to be 40 ft. distant from the object of attack.

The exact principle on which the torpedoes are to be discharged is kept a secret by the constructors, at the request of Admiral Porter, who does not wish his invention to become known to natives of other countries. Numbers of gentlemen connected with naval construction in European countries have visited the Navy Yard and endeavored to get some idea of the construction of the new torpedo boat, but have been met by the officials with a polite refusal.

To guard against any possible leaking out of the secrets involved in the construction of this boat, the men engaged on it can form no idea of the whole, as they are given work piecemeal.

From all that can be learned, however, concerning this new engine of destruction, it is fair to infer that Admiral Porter will have given to the American Navy the most powerful and destructive weapon ever invented. It is being pushed rapidly forward to completion, and will probably be ready for launching in the latter part of July.

ASIATIC RAILWAYS.

From "Iron."

The glamor of romance still clings to the East. Even the keen, money-loving, practical Frank is unable to resist Oriental influences, and when brought face to face with the principalities and powers of the East, conceives enterprises of pyramidal grandeur. Englishmen were startled to hear, the other day, that the Shah of Persia had made what is euphemistically termed a concession to Baron Reuter—the said concession giving power to the fortunate holder to "run" the entire Persian Empire for his own especial benefit, subject, of course, to a certain percentage payable to the Shah. In this nineteenth century of ours, people are accustomed to "big things." Stupendous contracts are quickly made, and punctually performed, but the idea of managing an Oriental empire—finance, roads, crops, mines, earth, air, and water, "stock, lock, and barrel"—by contract, is certainly new, and reflects the greatest credit both on the courage and the originality of the high contracting parties.

Hardly have we recovered from the shock occasioned by the Persian concession, when another great enterprise springs into life at the bidding of M. Ferdinand de Lesseps, a gentleman whose career has proved that he has not only the daring imagination necessary to the conception of a great scheme, but the steady persistence so indispensable in bringing happy ideas to fruition. It must never be forgotten that, in the case of the Suez Canal, M. de Lesseps was right, and the English opponents of the scheme steadily and obstinately wrong.

Through good and evil report M. de Lesseps adhered to his grand design, and has had the satisfaction of beholding its success. We would therefore wish to speak respectfully of any plan due to the fertile

brain of him who made Africa into an island, but at the same we cannot refrain from expressing some astonishment—not at the vastness of the scheme—but at the cosmopolitan objects proposed to be attained by the Central Asiatic Railway from Orenburg to Samarcand, Bokhara, and Peshawur, completing the line of railway from Calais to Calcutta.

With touching confidence in mankind, the distinguished Frenchman assumes that an unbroken iron road, 7,500 miles long, passing through the territories of the Czar, to British India, will at once do away with all heartburning on the Central Asia question, and that—if not the lion and the lamb—at any rate the lion and the bear may indulge in friendly hug on the snowy summit of the Hindoo Koosh.

So far as the 1,500 miles of railway from Orenburg to Samarcand are concerned, the project touches Russia alone; and as, in the pursuance of her ambitious designs upon Central Asia, such a railway would be of great utility—to Russia, be it well understood—there is little doubt that, for Imperial and strategical reasons, the line will sooner or later be constructed by Russia herself. There can be no possible objection to such an arrangement; and if Russia in her benevolence should feel inclined to extend, at her own expense, the benefits of railway communication to semi-barbarous and not-yet-annexed States, such as Bokhara, no nation possesses the shadow of a right to say her nay; but it is futile to attempt to represent the scheme as one likely to enlist the sympathies of Englishmen. That the States existing between Bokhara and Peshawur are independent, would probably appear but a slight objection to the Russians, who are certain—if allowed to pursue their career of conquest unchecked—to push their successes to the foot of the great mountain barrier which divides India from Turkestan. Putting aside the tremendous engineering difficulties which would be encountered in driving a line from Bokhara through the massive buttresses of the Hindoo Koosh to Peshawur, we conceive that a trans-Russian route to India is that of all others least likely to commend itself to the English mind. The only enemy—worthy of the name—with whom we are likely to come into collision in Asia is Russia; and it is, therefore, of the last importance that the high road to our Indian possessions should be carried through the domains of any other potentate rather than through those of the Czar.

It would be vain to deny that grave objections may be urged against all the railway routes to India hitherto proposed. In "piping times of peace" the Euphrates Valley line, continued along the shore of the Persian Gulf and the coast of Beloochistan to Kurrachee, clearly offers more attractions than the roundabout route through Cracow, Orenburg, and Peshawur, especially when it is considered that more favorable arrangements as to customs could be made with the Persian than with the Russian Government. But again a dilemma presents itself.

Railways can only be built with two objects. One of these is to pay a dividend in time of peace, the other is to serve as military roads in time of war. We submit that neither the Orenburg nor the Euphrates Valley lines will fulfil either of these requirements. The countries to be traversed by them are poor and sparsely populated; therefore the lines, commercially considered, would be failures. During war the high road to India would be in the hands of independent and possibly hostile States. It is difficult to see how the construction of either or both of the projected lines could serve England either commercially or strategically.

Travelling farther eastward, we encounter an important but purely commercial problem. This is the opening of a new route to Western China, with the object of bringing the inhabitants of Yunnan and Szechuen into communication with the Western world. The mineral wealth of Western China is almost incalculable, but inexhaustible supplies of coal and iron are rendered useless by the absence of practicable roads.

So long ago as 1856, it occurred to the Governor of Saigon that the trade of Yunnan might be advantageously diverted through the French possessions in Cochin-China, and an expedition was organized to explore the upper course of the great river Me Kong. Conducted with great courage and skill, this enterprise laid bare the disheartening truth that the rapids and cataracts of Khong interpose an insurmountable obstacle to the navigation of what would otherwise prove one of Nature's most magnificent highways.

While the French were busily exploring the Me Kong, our own countrymen were

directing their attention to the Irrawaddy, with the object of bringing Chinese traffic through British Burmah to Rangoon. Various lines of railway have been proposed, and it is by no means improbable that one of these may present sufficient attractions to the English and Burmese Governments to secure its adoption. When a line of railway is once brought up to his very doors, there is little doubt that the patient, industrious, and imitative Chinaman will not be slow to recognize the merit of the new road.

A single glance at the map will show the great advantage of the Burmese route to Rangoon over the ancient course of trade through Canton or Foochow and the Straits. Another opening will be made for the introduction of English goods into the interior of Asia and the initiation of a traffic of immense magnitude. It is late in the day to compete against Russia for the trade of Central Asia. Not only has she, by the imposition of prohibitive duties, closed her conquered provinces against all goods but those supplied by herself, but has, in addition, imposed a system of differential duties upon those States which have not yet exchanged the name of ally for that of vassal. By constantly pushing her protective tariff in advance of her own movements, Russia has succeeded in gradually elbowing the British trader out of Turkestan, Kashgar, and Bokhara. It only remains for him to vindicate his vitality by pushing farther eastward and developing a new trade with the teeming population of the Celestial Empire.

STREET LIGHTING.—THE USE OF LENSES AND REFLECTORS.

By T. A. SKELTON.

From "Journal of the Society of Arts."

The subject of artificial illumination has for many years engaged a large share of scientific attention, but perhaps public notice has never been more forcibly drawn to its consideration than at the present time.

The increase in the price of coal, and in cost of labor, has resulted in a general advance in the price of gas. This circumstance has favored or necessitated the introduction of improvements in the manufacture of ordinary gas, and has encouraged the promotion of inventions for the production of illuminating gas from other materials than coal, and it has also brought into prominent notice other means of obtaining artificial light.

These questions will probably attract even yet more attention during the present year; and as "Artificial Illumination by all Methods, Gas and its Manufacture," is to form one of the chief subjects of the London International Exhibition in 1874, it may be anticipated that the public, as well as those more immediately concerned in the details of these questions, will look to that Exhibition, not only for a full and complete representation of the subject, and for a comparison of the rival methods for the production of artificial light, but also for an illustration of the means of using it with the greatest economy and effect.

It is with the utilization of artificial light that I have the honor to engage your attention this evening, and I shall first beg leave to impress upon your minds the fact, that however successful the attempts to improve the methods of the production of such light may be, either in increasing its intensity or in diminishing its cost, the scientific application of lenses and reflectors will still be for some purposes absolutely necessary, and for many others will give valuable aid to artificial light by yet further increasing its lighting power, by controlling its direction, or by reducing the quantity of light necessary to produce a required effect of illumination.

The optical principles upon which the action of lenses and reflectors depend are so generally well known, and were, in the first series of "Cantor" lectures in the present session of this Society's proceedings, so minutely explained, that I need only very briefly refer to them on this occasion.

Firstly, you are aware that light, meeting with a reflecting surface, is deflected from it at an angle equal to the angle of incidence.

Secondly, that a prism of glass may be employed as a reflector by using the internal and total reflection from what we may term the interior of one of its sides.

And, thirdly, that light passing through

a transparent body, such as a lens, will be refracted from its original course into a new direction, dependent upon the refractive power of the material, and the angles of its surfaces in relation to the course of the light.

We have thus two practical means by which to control the direction of course of light: reflection, by the use of catoptric reflectors or prisms; and refraction, by the use of a dioptric lens; the use of either or both in combination will depend upon the use to which the light is intended to be applied—or rather, in fact, upon the amount of deflection of the light necessary to be produced.

Artificial illumination for useful purposes may be broadly classed under two heads. First, Signal lights; second, Artificial light as a substitute for sunlight. Now, although it is my intention to treat more particularly of the second of these two divisions, yet as the application of lenses and reflectors has hitherto been more scientifically and successfully studied in relation to signal lights, and such application, after passing through years of practical experiment and use, has at last, in the modern "Catadioptric" lighthouse light, reached a completeness that may be deemed almost if not absolute perfection, it may be advantageous to sketch out briefly the progress of science and invention in that form of artificial illumination, as a help to our consideration afterwards of the question as to how far the principles and means so successful in regard to signals may be practically applied with advantageous results in other uses of artificial illumination.

In its simplest form a signal light would be represented by a flame radiating its light into space in every direction, and consequently diminishing in intensity as the square of the distance increases; such indeed was the feeble characteristic of our lighthouses or beacons up to the beginning of the present century.

The first improvement made was the use of a parabolic reflector; this form of reflector, as you are aware, throws forward in parallel lines the reflection of a light placed in its focus, thus concentrating about one-half of the light into a single direction, but entirely obscuring the light in the opposite direction, so that if a fixed light was required to be visible over the entire radius of the horizon, or any large portion of it, a number of lights and reflectors would be required.

At the North Foreland Lighthouse, a lens was placed in front of each flame, in addition to the parabolic reflector; but these lenses, which had cost £50 each, were found to be useless in such a combination, and were removed in 1835; in fact it is impossible to obtain any advantage by the use of a dioptric lens in conjunction with a parabolic reflector, as the direct rays of light impinge upon the lens at a different angle to that of the reflected rays, and hence one or the other must be dispersed beyond the required direction.

To return to our lighthouse illustration, we find that about the year 1822, Fresnel introduced in France the method of concentrating light for lighthouses by the method of refraction, using a dioptric lens of a novel but scientific form. The great advantage of this system was that, by dispensing with reflectors behind the flame or light, the light was visible round the whole horizon, so that one light only was now necessary, and far more of the light was utilized than by any previous method. Fresnel's admirable system has, however, been improved upon by the addition of prisms, acting by reflection, placed above and below Fresnel's dioptric lens, intercepting and utilizing rays of light far beyond the power of a dioptric lens. Thus nearly the whole of the light produced is usefully employed by being compelled to travel in a plane parallel to the horizon. This is the form of lighthouse light known as the "catadioptric," from its combination of the powers of both reflection and refraction. It is now used in our best modern lighthouses. The diagram I have here represents the North Foreland Lighthouse, erected in 1858, and it is a system that may fairly be considered as the perfection of the application of reflectors and of refracting lenses to signal illumination.

Having thus merely brought the leading principles and illustrations of this part of my subject before you, I have now to ask your attention to its second division—the use of artificial light as a substitute for sunlight; and in tracing the course of invention in relation to the use of lenses and reflectors as aids to this form of artificial illumination, I shall have to refer to many unsuccessful schemes, giving them, however, only sufficient attention to explain the cause of their inutility, and we shall meet

with but few inventions or proposals which have achieved or even deserved success.

Allow me first to divide this branch of our subject into two distinct subdivisions—light used within an enclosed space, having reflecting surfaces, such as an ordinary room, and light used in an unenclosed space, in fact, open-air illumination.

The essential difference of these conditions must be familiar to you; you cannot fail to have noticed how a lamp or candle, which in a room or hall with light walls and white ceiling had appeared cheerful and brilliant, suddenly seemed to be deprived of its energy, and looked dismal and feeble when removed into the open air at night. The intensity of the light was the same—the circumstances under which it was burning alone had changed.

For ordinary indoor lighting the reflection of light by the walls and ceilings is usually sufficient, and insures a fair and even diffusion of light throughout the space illuminated; shades are usually placed on lamps more to protect the eye from the direct rays emanating from the light than from any reflective power they possess; and where in the passages of public buildings or in other places, silvered reflectors are placed behind the flames of wall-lamps the effect is nearly always more dazzling than advantageous. It is, therefore, in the use of artificial light in the open air that the aid of lenses and reflectors is in fact required; and we may take for an illustration an ordinary street-lamp; any improvements in such lamps will probably be useful in many other situations.

As in the case of the early form of signal light or beacon in the last century, so an ordinary street-lamp of this day radiates its light into space in every direction; some few of the rays may faintly illuminate the walls of adjacent houses, but in any case a very large proportion of the light produced is absolutely wasted. Long ago this fact appears to have attracted attention, and early in the history of street-lighting, attempts were made to utilize the wasted rays of light. We find records of these efforts among the specifications at the Patent Office dating as early as 1791, when the first use of lenses in connection with street-lamps appears to have been proposed. In 1793 two other inventions for the purpose are recorded, and all these seem to have been various and ineffective forms of the dioptric lens applied to the globular oil lantern.

Passing over the various improvements in the lanterns used for oil lighting, we come to the earliest form of street-lamp used in gas lighting in this metropolis. I have here a sketch of one of these from Lincoln's-inn-fields; these had solid metal roofs, probably once polished or whitened in the interior, but now rusted and blackened. Even at their best they could have reflected to the ground only a very small amount of light, while they effectually prevented the adjacent buildings from being illuminated above the level of the lamp when the flame was placed at the usual height in the lantern. The first improvement in these gas lanterns was simply to roof them with glass, as is the common practice at this day. These lamps certainly had a lighter appearance, and were at least not worse than their predecessors except in their greater liability to breakage. Still anything like a scientific application of lenses or reflectors to control the direction of the light was not—at least so far as I can ascertain—attempted, until Sir Goldsworthy Gurney obtained patents, in the years 1841 and 1842, for his improvements in regulating and dispersing light and heat. These, however, required the use of an argand burner and glass chimney, and were not of a character suitable for the rough usage or careless cleaning usually given to a street-lamp, nor were they, indeed, specifically proposed for this purpose.

In 1854 we find a proposal, by Messrs. Boggett and Pettit, for the use of what they termed "dioptric refractors." These were annular reflecting prisms, and their application, among many other purposes, was proposed as an improvement in street lighting. This was to be effected by dividing the ring into semicircles and placing them on either side of the gas flame, at an angle of about 45 deg. Either the cost of making these prismatic lenses, the danger of breakage from the heat of the flame, the practical difficulty of cleaning, or the very slight benefit to be obtained by their use in this form, must have proved a sufficient reason for their not being adopted for use in street-lamps.

Reflectors, of parabolic and other shapes, have often been placed behind the flame in street-lamps; commonly two flames were used with two reflectors back to back between them, while, even recently, another form of this attempt at improvement has been the subject of experiment in Paris,

when silvered glass globes, about 3 in. in diameter, some flattened on opposite sides, with two gas flames, and others flattened on three faces, with three gas flames, were fixed in the lanterns in the Place Vendome. These experiments resulted in absolute failure; no increase of light was obtained, and the glass globes were fractured by the heat of the adjacent flames. Indeed, a successful result was impossible; and any form of solid reflectors intercepting the rays of light visible in the street in any direction, is simply absurd and wasteful in application to street lamps.

We may now dismiss, with these few examples, any further consideration of arrangements of lenses or reflectors requiring to be placed inside the lantern; they would necessarily be in danger of damage or destruction by the flame used, and interfere seriously with the cleaning of the interior of the glass lantern, besides themselves requiring great care in cleaning and polishing, without which they would be useless.

Here, then, is the broad distinction between the application of lenses and reflectors upon the large scale of a lighthouse, where each single part can be separately cleaned, and a similar application of lenses and reflectors to so small an object as a street lamp.

I must now invite your notice to some arrangements of reflectors which, forming part of the lantern or its glazing, appear to be free from some of the difficulties I have noticed, and which have for different purposes been successful in various degrees.

The simplest of these arrangements is the use of solid reflecting plates in the roof of the lantern. This, under various forms, has been the subject of many patents; it is, however, of use only when an increase of light is desired close under the lamp, and where, cutting off from adjacent building all the light above the level of the lamp is of no importance; but as a consequence of this concentration of light close under the lamp, this arrangement is entirely unsuited for ordinary street-lighting, as, unless the lamps were placed much closer together than at present, the intervals of darkness between the lamps would, by comparison, be rendered darker. Examples of this principle may be seen at Primrose-hill, in the globular lamps there, but the result is anything but satisfactory.

Another form of solid reflecting roof may be illustrated by a diagram representing the large lanterns now in use in the London and South-Western Railway yards at Nine Elms; it is evident at a glance how small a part of the waste light is intercepted, and how little concentration even of that is effected; the inverted cones were, I believe, originally polished, but now are simple white surfaces, from which the light radiates freely in all visible directions; in this apparatus a glass tube or chimney is required to protect the reflecting cone. Some street lamps of this character may also be seen in the Strand, opposite Exeter Hall, and it will readily be seen there how little aid is obtained from reflectors in this form and position.

Leaving the use of solid reflectors as valueless for general application, we turn to the next series of proposals—that in which the sheets of glass used in glazing the lantern are used also to divert the rays of light.

The first of these is the use of opal glass in the roof of the lantern; this, while acting chiefly as a solid reflector, and subject to its disadvantages, yet permits a small portion of the light to pass through its substance; but even this small quantity is radiated in all directions visible from the surface of the opal glass, so that little or no control is obtained of the intercepted rays. A few specimens of this system may be seen in Oxford street, but it will require careful searching to discover them, or to see the difference between them and the other street-lamps at a slight distance, especially if the other lamps, not having been recently cleaned, present a very dull appearance.

We next have a suggestion for cutting the upper part of the side panes into lines and facets, something after the manner of a cut-glass decanter; the small advantage gained by this method was certainly not worth the cost.

A more scientific application of dioptrics was proposed in 1857 by Degrand, who obtained a patent for what he described as "Lenticular Glasses." These appear to be a modification or variety of the dioptric lenses introduced by Fresnel, and for calculating the forms to be given to the striæ or waves of the improved glasses. The formulæ of Fresnel are especially referred to because of their accuracy. These glasses, among various other uses, were designed for street-lamps. I am not aware that the invention ever took a practical shape in this

direction in England, and the great cost of manufacturing such delicate optical glasses in thin sheets with sufficient accuracy and polish—and without either they must have been worthless—probably prevented their application to street-lamps.

Recently, another form of this application of the dioptric lens was experimented upon in Paris; in this case the lantern was a a cylinder formed of thick glass panes, cast in the form of a dioptric lens, such as may be seen in some ship-lamps; the light was entirely obscured from direct view, and the plan was found upon trial quite unsuited for street purposes.

We have now traced the course of invention in street-lamps, beginning with the simple flame, as we did with the simple beacon light in the case of signal lights; and, passing through the stage of parabolic and other reflectors behind the flame, into the use of various forms of the dioptric lens, we arrive at the year 1871, without further progress in the application of lenses and reflectors to street lighting than the state of advance in signal illumination in 1822, when Fresnel introduced his dioptric improvements, and practically without any really useful application of the principles of reflection or refraction to this important public use of artificial light.

We have seen in the case of lighthouse lights how perfection in principle has been reached by the addition of the catadioptric or reflecting prisms to Fresnel's dioptric or refracting lenses; we have also seen how powerless the dioptric lens is to assist us in street-lighting. Let us then consider these catadioptric prisms—these additions which have secured such good results in signal lights, and see how far their use may serve our purpose in street illumination.

We readily perceive their power to control the direction of light reflected by them, and how far beyond the range of a dioptric lens that power extends. We see also that they can be applied above the level of the flame, so as to not intercept in any direction the direct action of the light usefully employed, but the difficulties we find in their use are the cost of accurately-shaped, polished glass prisms, their weight, and the great trouble of cleaning them. How, then, shall we obtain the evident advantages their use might confer, and avoid these difficulties? The course is easy enough, as the action of a reflecting surface and a reflecting prism is identical; use thin reflecting plates instead of prisms, and so obtain at once economy and lightness, and avoid the necessity of cleaning each separate reflecting plate, by enclosing each group of reflectors between plates of glass set in a metal frame.

I have here a specimen of the street-lamp now known as the catoptric lamp; this will serve to illustrate the manner in which these reflecting plates can be applied. The angles at which the reflecting plates are placed in this specimen are such that, while they intercept light radiating upwards through 53 deg. of arc, they concentrate it within an arc of 15 deg.; this gives sufficient dispersion of the reflected light over the dark intervals between the lamps in a street; by varying the angles of these reflectors we can perfectly control the direction of the reflected light. In appearance you perceive three points of light, —first the flame itself; then, through the group of reflectors at the side of the lamps, an inverted image of the flame; and in the group of reflectors in the roof, a second inverted image of the flame; this, from reflecting the edge of the flame, or rather the flame in a more concentrated shape, as viewed from the position of this group of reflectors, gives an image of the flame even more brilliant than the appearance of the flame itself.

The concentration of the light radiating through 53 deg. of arc into a much smaller area gives this reflected light its brilliancy and penetrative power, as in the example of the modern lighthouse light. There, however, the rays of light are concentrated into parallel planes, and here we have them extended over such degrees of arc as the amount of concentration or diffusion we desire may necessitate.

This system of street-lighting was introduced upon one side of Waterloo Bridge in November, 1871, and so satisfactory was the result, that soon after, both sides of the bridge were fitted with lamps of this description, and the daily press described its effect in terms of the highest praise.

Lamps exactly similar to the pattern before you are in operation in Moorgate street and many other parts of this metropolis; and in the town of Southampton the High street, one-and-a-quarter miles in length, is entirely lit with them, and the brilliant appearance, the increased lighting power, and the even diffusion of light in that street has given the greatest satisfac-

tion. Numerous other towns have these lamps on trial previous to a general adoption of the system.

It is obvious at a glance how different this application of reflectors for street lighting is to all which have preceded it, and how great is the variety of form and detail of which it is capable. Here we have a specimen with reflecting plates fluted vertically; no advantage in power is, however, obtained by it, and although the effect may be pleasing, its extra cost would perhaps prevent its use in ordinary street lamps.

This question of cost brings me to the commercial question, whether the use of reflectors and lenses in street lamps, admitting its practicability, is of sufficient advantage to warrant the increased cost of the lamps and apparatus and the possibly increased cost of maintenance, or whether we can balance the extra cost, or entirely save its annual equivalent, by a saving in the amount of lighting material consumed, and yet give at the same time double the useful effect of the present lighting. Let us see. Here we have lamps of various patterns all burning gas from the same main, each at the rate of 5 ft. of gas per hour. These street-lamp regulators are by Mr. Sugg, of Westminster, all carefully adjusted, and giving, as you see, even results. Now in this specimen of a catoptric lamp, I have a regulator, allowing a flame to burn at the rate of 4 ft. of gas per hour only. The great increase in lighting power is still apparent to you; and at least double the lighting power is given by this lamp, as compared with the others burning 5 ft. of gas per hour. Here, then, is a saving of 20 per cent. in gas, or about 13s. per annum. This would actually pay the entire extra first cost of the lamp and reflectors in two years, and practically the cost of repairs has not been found to be much more than the cost of repairing an ordinary lamp.

The question of cost cannot, however, be considered, as if our present street lighting was so satisfactory that no improvement was desirable or necessary. The want of efficient street lighting in our cities and towns is an acknowledged grievance of long standing. London has been declared to be the worst lit city in Europe, and every one must admit the dangerous darkness which prevails in streets without shops, or after the shops are closed in others, and we depend only upon the public lamps for illumination.

How, then, is this defective lighting to be remedied? How are we to obtain at least double the present lighting?—and less than double will not be satisfactory. Will the authorities be induced to double the number of lamps we have at present? It seems hardly probable, when such an outcry is raised against a few shillings per lamp increase in the cost of gas, or when we remember that in 1866, according to a Parliamentary Report, there were about 40,000 public lamps in the London district alone, costing, at the present average of £4 per lamp, £160,000 per annum, while we cannot fairly estimate the total number of open-air lamps in this country at less than 300,000.

It is, therefore, I think, obvious that it is to the use of reflectors, properly constructed and applied, which will in reality utilize to our advantage the hitherto wasted light, and which are of such a practical nature as to be fit for the rough work of public use, that we must look for immediate relief from the prevailing street darkness.

The use of such means, if not only doubling the present lighting power of our street-lamps, but also insuring a more equal diffusion of light over the whole course of our streets, would be a boon worth paying even an extra amount for; but when these advantages can be actually obtained without extra cost, as I have shown they may be, then, slow as the introduction of any improvement ever seems to be, strong as may be the power of prejudice or of interest, or powerful for resistance as mere apathy or indifference may prove, it seems difficult to believe that the increased street lighting demanded by the public can long be refused to them by their representatives when the power of obtaining that increase on such terms—an increase that means better protection to life and property—is absolutely and practically at hand.

MR. PLIMSOLL'S appeal on behalf of our seamen has caused the Government to grant a Royal Commission for the purpose of investigating into the nature of the very serious charges that have been made against the employment of unsafe and unseaworthy ships by some shipowners.—*Naval Science.*

CHIMNEYS FOR FURNACES, FIRE-PLACES, AND STEAM BOILERS

By R. ARMSTRONG, C. E.

PRACTICAL THERMODYNAMICS.

Furnaces, or closed fire-places, which it is the main design of this essay to treat upon, are essentially different in principle and construction to the ordinary open fire-places of dwelling-houses, as they are exceedingly different in their general scope and object, and in the vast variety of their applications; yet there is one thing common and important to both, and that is the chimney, or vertical flue, for the purpose of creating a proper draught of air through the fire, as well as to carry off the smoke, or other products of combustion; and it is in the generally increased proportions of this almost indispensable adjunct to all furnaces which principally distinguishes the modern from the ancient practice of steam engineering.

The great developement of the manufacturing system of this country during the last twenty or thirty years, and the erection of a larger description of factories being required, has caused more attention to be devoted to the stability and general economy of such structures, in which the erection of larger chimneys than formerly have in some degree participated, but only to a trifling extent from professional architects, properly so called. The external portions of the chimneys of dwelling-houses have, no doubt, had some share of attention from architects, but it may be doubted whether the most important function of even a house chimney—the creation of draught—has been adequately considered, if even only to prevent that greatest of all nuisances, a smoky house. In proof of which, many cases might be cited among the mansions of the nobility and gentry all over the country, as well as in town, where it is the less excusable. Indeed, the chimney flues of dwelling-houses are too commonly treated as mere conduits for smoke, as, in fact, they are frequently termed, and as such they are considered equally subordinate with drains and other conduits, which may or may not be attended to after the plan of the house is determined upon, and, in some cases, even after the house is partly erected, instead of being—as I humbly think they ought to be—considered, in an architectural sense at least, of the highest importance, as they are, in fact, the highest external features that can in this climate properly characterize the well-ventilated, well-warmed, healthy, and comfortable dwellings of a rational and civilized community.

It is far from my intention to write a homily on any branch of architecture as an art, but it must be admitted that there are few, if any, subjects of such useful importance connected with architecture that have been so much neglected, misdirected, and misunderstood, as the proper construction of chimneys generally, or their proportions most suitable to the various purposes for which they are designed. Such attention as house chimneys have hitherto received, has been too commonly in respect of their ornamental and decorative character only, even to the extent of erecting fictitious chimneys where there are no flues and none wanted. For all purposes of real utility the house-building architect too often, apparently, contents himself with a single step, and in some respects scarcely so much, in advance of the "hole in the wall" of the ancient Romans, who, however, with all their barbarous simplicity, were, at any rate, never troubled with down draughts—the universal malady of all English smoky dwelling-houses.

The labored ornamentation of housetops, with their numerous little crooked outlets for smoke, though frequently only inlets for wind and rain, mis-termed chimneys, have been the chief degradation of modern architectural science. The art of erecting chimneys for steam-engines, and for similar purposes, has, however, fared somewhat better, since all the more substantially useful part of architecture, comprising nearly the whole of that appertaining to manufacturing industry, has for some time past, in our northern counties at least, merged into the province of the civil and mechanical engineer, technically known in Lancashire as the factory engineer.

Factory engineers, however, though differing widely from architects generally on many points, are not at all agreed among themselves as to the best form and construction of a chimney for attaining the principal end in view; namely, the best draught at the least expense. In short, the problem of how to give a sufficient velocity to the air passing through the fire-

grate, with a given temperature in the furnace or in the escaping products, and at a minimum rate of consumption of the fuel to be used, has scarcely yet received an adequate solution, even theoretically. Practically, the question has received many solutions—too many, one may say, for the convenience of ordinary business men—which circumstance is one of the main causes that has rendered the present work necessary, as well as contributing to some of its chief difficulties. The multitude and diversity of opinions on this subject may, in a great measure, be ascribed to the generally prevailing reliance on the dicta of some few popular professors, or rather amateurs, of chemistry; in which category we might also, perhaps without much injustice, include a few so-called scientific guide-books. I am not for decrying the present inundation of cheap scientific treatises, which is so marked a feature of the times; but, on the contrary, think such books cannot be too many nor too cheap, when original or genuine. Such of them, however, as are merely reproductions of the last century, or even the early part of the present, are generally to be deprecated.

To make a chemical laboratory, for instance, as has sometimes been done, an object of study to the engineer or builder, however scientifically constructed and arranged, unless, indeed, the object be to erect another laboratory for a similar purpose, is, to say the least, very injudicious, and the fruitful source of much error and prejudice in the minds of young men of scientific aspirations. More particularly is this the case when the object in view is the arrangement of factories or works for other special purposes; those purposes being mainly for commercial profit, and not for the mere amusement of amateurs, nor even for the professed advancement of science, which is often little better.

Holding the above views in common with the factory engineers before adverted to, I have always preferred taking for precedents the blacksmith's forge, the potter's kiln, or the glasshouse chimney, rather than seek mechanical prescriptions, so to speak, among the crucibles and alembics of our "modern alchemists."

With respect to the fire-place itself—the Furnace—to which a chimney of some kind is but a necessary though highly important accessory, it is altogether in a different predicament. The chief peculiarity relating to Furnaces, is that they have always been, and are necessarily, in the hands, or constantly under the immediate control, of the workman himself. To him they are, in a certain sense, his tools—the tools of his trade—and for each special trade comparatively perfect, at least he thinks so. Operative workmen, at any rate, though "reformers" they may be themselves, seldom willingly admit of any reform in their work tools. On this point they are essentially conservative in all trades, even to the cobler, as he sings, "To lose my awl 't would break my heart," etc. The consequence of this general feeling is that we have an abundance of experiments confirmatory, or otherwise, of any particular innovations or alterations in a chimney or furnace that affect the draught, which is the only result a workman cares about. If the alteration turns out an improvement, it is quickly, and almost instinctively, as it were, appreciated; if the reverse, or doubtful, or if even only undecided, it is as quickly rejected and condemned. Generally rather too quickly, in fact, for the interest of such inventors and improvers as cannot afford to wait for matured results. Hence has arisen a good deal of that great diversity of opinion, not to say theory, even among the most observant of mechanical engineers themselves.

The Chimney and Furnace have not been sufficiently considered together, or as one apparatus. The Forge furnace, the Steam Boiler furnace, the Baker's Oven furnace, and the Brick-kiln furnace, may be instanced as four examples of great dissimilarity of purpose; but from the first to the fourth consecutively, requiring a gradually decreasing velocity of draught. The first and the last of the series, being instances of the two opposite extremes, requiring the quickest and the slowest draughts, and having in consequence the highest and the lowest temperatures. These two extreme cases, moreover, have one peculiarity in common, which is, that it is by many considered a difficult matter to decide in either case where the furnace proper ends, and where the chimney flue begins. Al hough I shall have to revert to this point more fully in the sequel, it may here be observed that the difficulty alluded to may be greatly lessened by considering that the termination or vent of the Forge or Air furnace for working iron ought to be at no great distance beyond the point of greatest

temperature of the flame, because, in the Forge, or Iron furnace especially, it is the flame that "does the work." Whereas in the other extreme case mentioned—the Brick-kiln—which requires little or no flame, the furnace may be considered to terminate at the lowest possible temperature of the issuing hot air, and might in fact do very well with hardly any chimney at all. The other two kinds of furnaces referred to—the Steam-engine furnace and the Baker's Oven furnace—may be considered generally in an intermediate condition to the above, or in the order in which they are stated, more particularly as respects strength of draught. These two furnaces have also one trait in common, in so far as they both require regulating while at work, and are capable of permitting of variations of temperature through a very considerable range. The steam boiler furnace admits of great delicacy as well—so much so, as to make it, when supplied with proper self-acting dampers, a very efficient regulator or governor to the steam-engine itself. In the Oven furnace, the draught requires to be "sharpened" or slackened, from time to time, by hand, to suit the kind of goods undergoing the operation of baking. The steam-engine furnace is like the forge furnace, so far as it requires occasionally a very quick action for raising the pressure of steam in a short time, or otherwise, to prevent the steam from going down by some sudden increase of the load on the engine. The Oven furnace is not subject to such sudden changes, but rather requires a long continued, persistent, steady heat. This property of the Oven furnace is mainly caused by the large mass of brick-work with which it is commonly constructed, absorbing and retaining a great deal of heat to begin with.

The accumulation and retention of heat, or of the power of heating other bodies, by non-conducting or slow-conducting substances used in the construction of some furnaces, and the rapid dissipation and apparent extinction of the same, by metallic, or good conducting substances, in connection with other furnaces so provided, is perhaps the most interesting branch of this subject. And as anything bearing on this that may serve to elucidate the principles on which sound practice, to say nothing of theory, must be sooner or later established, this introductory Essay appears to be the proper place in which to introduce what is either new, or differently treated and usual.

In following the course here indicated, I am quite aware of the unmethodical appearance it must have; but I have always preferred the rough and useful, though only prospectively recompensed labors of the pioneer's track, to the smooth greensward and well-worn walks of science that often lead "to nowhere." Satisfied if, in going through the still unexplored fields of discovery, I can bring home but a few rough logs towards the building up of the edifice so recently founded for sheltering the yet young though promising science of Heat and its relations, now termed Thermo-dynamics.

For the actual state and condition of much of existing knowledge on the subject of heat, there is now no longer occasion to go for comparisons back to the times of Bacon, Newton, and Hooke, much as is due to those illustrious philosophers. Nor is there any occasion to consult the works of Franklin, Black, Rumford, and others of their times, nor adopt any of the theories and doctrines they promulgated. The opinions of those much more reliable authorities—even Young, Dalton, and Davy—cannot now be taken without some little reserve; but the experiments of their distinguished successors Faraday and Joule, with the praisworthy labors of Rankine, Tindal, and a few others in the same direction, have more recently furnished results on the subject of the present inquiry which cannot be too highly esteemed, and which, with this general acknowledgment, I intend to make a free use of in the course of this work.

There is no need to extend the present Essay by any long dissertation on the theory of Chimney draught, neither shall I introduce much of what has been advanced by others on that subject, but rather confine these remarks to such elementary facts, principles, and rules, as are likely to be useful to those practical engineers, builders, and others, whose commercial undertakings —contracts and other exigencies—do not generally admit of long delay, much study, or scientific research, but who, nevertheless, may wish to readily avail themselves of a few leading principles and practical directions, such as may at least prevent them from getting very far wrong. By propounding and exemplifying a series of practical examples of cases that can be now referred to in actual use, it is hoped that

the most casual reader will be able to accompany me with confidence and satisfaction through the rest of these Essays.

THE STEAM-ENGINE CHIMNEY.

The questions of most interest in connection with large chimneys, and those usually the first asked, after the important one of cost, by the capitalist who has determined on some considerable outlay, either in erecting a new shaft or rebuilding an old one, may be classed under two principal heads—namely, the external and the internal proportions.

Whether the external form of a hollow shaft of brickwork or masonry of considerable elevation, in this climate and country, should be a plain obelisk, or a finely proportioned architectural column, is a question that does not admit of much difficulty in deciding. Most engineers are no doubt properly inclined to the opinion that for so entirely utilitarian a purpose as a chimney, the former is the most preferable. It is, however, quite a matter of architectural taste as to how it may harmonize with surrounding objects, and the last thing in the world, perhaps, that engineers ought to dogmatize upon. Whether the form of such a column should affect great simplicity—a simple truncated cone or pyramid, for instance, decreasing uniformly in diameter upwards; or whether it should affect great stability, like the trunk of the oak, proverbially the shape for withstanding a severe gale of wind; or, ought a chimney shaft to be erected with a variable batter, like a lighthouse or a monument on the sea-coast—these are all questions requiring some consideration in designing a chimney for general purposes; but for the chimney of a steam-engine other especial requirements of far greater importance are to be considered.

It is the internal proportions of a chimney shaft only—its height and sectional area—that principally concern the steam engineer. Until these essential internal proportions are first agreed upon, we are not in a position to discuss the external proportions with advantage.

In fixing on the proper dimensions of the vertical smoke flue, or inside of a steam-engine chimney, it is a question with many, whether it should, as is most commonly done, be tapered internally or diminished in area towards the top; or whether it ought to be parallel—as wide at top as at bottom—in order to have the greatest velocity of draught. Or, again ought a chimney to be, as some few eccentric engineers contend, and occasionally carry into execution, even wider at the top than the bottom?

These questions are all deserving of attentive consideration, and will receive ample illustration in the sequel. But there is another question quite as important as any of the above, and requiring a prior consideration. It is thus enunciated: What are the proper dimensions—height and area—of a chimney shaft most suitable for a steam-engine of any given number of horse-power, or, which is nearly the same thing, for burning away a given quantity of coals per hour? The proper answer to this question depends a good deal on the quality of the coals used, and the quantity of waste gaseous products arising from their generally imperfect combustion in the furnace. The best Newcastle or Hartley coals, and the best Welsh steam coal, though requiring very different treatment in the furnace, are found equally in practice not to require such large chimneys as the inferior coals of the midland and manufacturing districts of England. Under these circumstances, it will perhaps be most advisable, in the first instance, to base our observations and calculations on such practical data as those districts so readily afford, more particularly those of Lancashire, South Yorkshire, Derbyshire, and Staffordshire. Another reason for adopting those data is, that the usual stoking and management of the fires in those districts may be described as a fair medium between the north and the south, between the Newcastle and the Cornish practice. There is one feature in common between the northern and southern practice that may be mentioned, which is, that the engines in both districts are generally very lightly loaded, compared with those in the manufacturing districts; the latter being very seldom indeed working at less than 50 per cent. above their nominal horse-power, and commonly more than double their real or indicated horse-power.

The last-mentioned circumstance furnishes us with the reason for the maxim so long prevalent in Lancashire, that a steam-engine chimney, leaving all considerations of cost out of the question, can never be too large nor too powerful, provided it is supplied with efficient means for checking the

draught, by properly fitted dampers or otherwise, whereby the supply of steam can be readily controlled at any moment, so as to work the engine at one-half its full power, and using considerably less than one-half the power of draught of the chimney; for which purpose, the ordinary damper (say 3 ft. long) of a thirty-horse engine ought to be open only to the extent of 3 to 6 in., thus having a surplus draught always at command for emergencies.

Another feature of this question, arising from the practice of working steam-engines with inferior fuel, is the large proportion of dirt and small ashes derived from the burning of the bad coal—the "flue dust"—which accumulates to an enormous extent within the flues and on the bottom of the chimney. Much of this flue dust—all the finer particles especially, and to a much greater extent than has hitherto been suspected, or at least recognized—passes up and out of the chimney top under the appearance of smoke, but which even veteran "smoke burners" generally are surprised to find is neither carbonaceous soot nor combustible gas, but principally incombustible earthy and silicious dust.

In appealing to the practice of our best engineers respecting the proper area of the vertical chimney flue of a steam-engine, there is no occasion to go back to the times of Brindley and Smeaton—when steam-engines were called fire-engines, and the firemen first called stokers—excepting for the purpose of making a single reference to the early practice of the celebrated James Watt, which strikingly illustrates, not only the difficulty of determining *a priori* the right proportions of a chimney, but also the admirable caution and prudence observed by him in this as in other matters, so remarkably conspicuous in the eminently practical mind of that great man.

After Mr. Watt had once ascertained the best size and proportions of a chimney most suitable for a given size of boiler and engine, he did not, at first, as almost any tyro of the present day would not hesitate to do—venture to throw the draught of two such or similar boilers into one chimney of a larger area, so that the same outlet might serve for the smoke from both furnaces, but he actually erected two such chimneys alongside each other! Or, occasionally, he did what was equivalent thereto: in erecting a chimney for two boilers, he would build up a midfeather, or division wall, from bottom to top, in order to separate the two draught currents from each other, in the same manner as in house chimneys. Had we not the evidence of yet existing erections to the fact, such a statement at this distance of time might be considered scarcely credible.*

From all accounts of Mr. Watt's early practice, it may be fairly inferred that he did not theorize much respecting the height of engine chimneys; for having succeeded in doubling the effect of the steam-engine itself, for the same amount of fuel previously used, he found no difficulty in making a low chimney suffice, such in fact, as were then in use for the old atmospheric engines, and occasionally to be seen in the mining districts at the present time. Those primitive erections, however—mere outlets for smoke—can now hardly be considered as chimneys at all, seldom exceeding an elevation of two or three yards higher than the top of the boiler. So soon, however, as the double powered steam-engine came into use, which quadrupled in effect the "old atmospheric," and often exceeded that, when applied to turning machinery in towns, it was found that the speed of the engine was often reduced for want of steam, and that again for want of sufficient draught. This last was occasioned, not unfrequently, strange as the words may now sound in the ears of modern engine drivers, by an "unfavorable wind!"

Prior to the times we are speaking of, the height of an engine chimney shaft, or stack of chimneys, as on Mr. Watt's system the chimney was, in fact, did not then appear to be of much consequence, provided it exceeded that of the neighboring buildings, and any precedents that then existed for the area of the aperture or exit passage of the smoke were like those for the height—of a very antiquated and empirical character. The size and shape of the superior orifice of a chimney was, in fact, even within the present century, regulated by no fixed rule, but was variously modified, as well also in diameter and area, from accidental circumstances—often by

* Two united chimneys of this kind were, not many years ago, in use, with two of Boulton and Watt's original 20-horse boilers, in the cotton-spinning works of Messrs. John Pooley & Sons, in Manchester. The case was remarkable, from the fact that the engineer of the firm once attempted to improve (as he thought) the draught of the chimney by breaking an opening through the midfeather, in order that the smoke might fill both the flues. The result was, the draught was entirely lost, and the communication had to be closed up again before the engine could be got to work.

considerations as to what could be made safely to stand, should the chimney require raising a little higher than usual, or than first intended. The numerous envious rivals of Boulton and Watt in the early part of the present century, the Sherratts, Murrays, and others of that time, whose almost universal rule was to give "one inch more in diameter of cylinder than Watt" for the same nominal horse-power, "and for a great deal less money," had no little share in helping to mend this state of things. They all knew pretty well how important it was to have a little extra steam, to meet the possible imperfect performances of their engines, and this a very few inches or feet of extra brickwork in the width and height of the chimney always gave them the command of, though this was often done at the casual suggestion of the bricklayer. In this matter, as with a corresponding suggestion of raising the height of the feed-pipes, which was often complied with professedly to suit the convenience of the stoker in preventing boiling over, it generally resulted in raising the pressure of the steam—an infallible remedy for almost all other deficiencies. Thus it occasionally happened that the trifling or crude suggestion of the bricklayer or stoker, in some instances, turned favorably the tide of success, which first founded the establishment of some of the largest engineering firms.

It is owing to similar circumstances to those just referred to that we have so many examples of engine and other chimneys in most of our old provincial towns, which, on being raised higher than at first intended, have been stayed from time to time by means of iron tie-rods, and hooped with iron bands. These iron rods, props, and crutches to chimneys are much resorted to in breweries, distilleries, malt kilns, and other large works, as well in London as in different parts of the south of England, and are very far from being any indication of want of great prosperity in the commercial and manufacturing concerns to which they are attached. In their apparent condition they are the very opposite to the establishments of even second-rate manufacturers in Lancashire.

So far as economy of fuel is concerned, the great prosperity and wealth of the former seems to be in defiance of extravagant waste and temporary expedients; while in the latter it arises in a great measure from well-considered permanent arrangements in all that concerns their engines, boilers, and furnaces. The necessity of artificial helps to the stability of a chimney is a sure manifestation of great waste of fuel, by unnecessary stoking and forcing the fires, and thereby overheating the chimneys, through inadequate area of flue. On the other hand, we may instance the air furnaces and kilns of the iron works and potteries of Staffordshire, where there is some degree of necessity for resorting to the expedients referred to, on account of the much higher temperature required by the process going on within the furnace.

The chimney, or cone, of an iron furnace, an earthenware kiln, or a glasshouse, is, in fact, a part of the furnace itself, or at least ought to be so considered, and necessarily becomes heated by the flame passing into, through, or among the materials and articles of manufacture it contains. This peculiarity, which is also common to many varieties of chemical furnaces as well as to pottery kilns, is the main cause of the very strong draught therein obtained.

In the case of a steam engine boiler furnace, however, it is well known that no such thing as the flame passing off into the chimney, nor even into a flue leading thereto, after leaving the bottom or internal tube of the boiler, is admissible with the slightest attention to economy of fuel. It requires but little consideration to convince us that the flame of a steam-engine furnace ought to be wholly expended against the boiler bottom, or, where internal furnaces or flues are used, entirely within the boiler itself, in which case the draught is created solely by the ascensional force of the column of waste air or smoke within the chimney, heated to the comparatively moderate temperature of 500 or 600 deg.

Thus it will be observed, there is a wide distinction to be made between these two species of furnaces; the steam-engine furnace approaching more nearly, in its moderate temperature, economy, and other circumstances, to the enclosed house stove, or at least to the kitchen fire-place, or cooking range. In these, the grate-room or furnace proper, and the chimney or smoke flue, are essentially separate and distinct parts, though in the best construction of engine furnaces they are rendered more perfectly so by interposing what has been always considered and properly termed the

flame chamber, or flame bed,* by practical engineers.

On the other hand, in the action of the air furnaces of a potter's kiln, in which the vertical flame chamber and chimney are both in one, or in the small furnaces of a chemist's laboratory, arranged for producing very perfect combustion and the most intense heats only, of two or three thousand degrees and upwards, we find a very different state of things to that of a steam boiler, requiring a heat only a little beyond that of boiling water.

The importance of the distinctions we have thus endeavored—though perhaps imperfectly—to point out, though well understood by practical firemen, has been much underrated, and the cause of some dogmatism and misapprehension, especially on the smoke question. From this mixing-up of different species of furnaces, intended for totally different objects and processes of art, though each may be practically perfect for the purpose it is intended for, very incorrect conclusions only have been deduced by some scientific writers. Waiving, therefore, for the present any further consideration in this place of the variable opinions of those chemists who have not yet been able to define satisfactorily where the steam-engine or other furnace (proper) ends, or where the chimney flue begins,—and dismissing also the calculations of those really able mathematicians on the subject of the velocity of draught, whose conclusions on the question have, unfortunately, differed from each other by nearly 500 per cent., we shall next proceed to describe the design for a steam-engine chimney, hastily inprovised for a particular occasion, and which, on being properly executed, happened to be right. We use this expression purposely, not wishing to claim any particular merit for the design itself, and do not say how many others we may have taken more pains with, that, from various causes, have turned out less successful, although as instructive lessons, some such may be referred to in the sequel.

In order to elucidate the object of this chapter still further, and to show what confused and erroneous notions on the subject of draught in chimneys have been, from time to time, prevalent, even in so generally intelligent and eminently manufacturing a town as Manchester, the following extract from a letter addressed to one of the newspapers in that city is inserted, together with my reply thereto. The article was entitled "Smoke and Long Chimneys," and commenced as follows :—

"The writer proposes that, instead of erecting a long chimney for a steam-engine furnace, a very long and wide flue or chamber should be built, contiguous to the furnace. Take an area of ten yards by twenty, more or less, according to the size of the furnace, wall it round 10 ft. high, and build three or four crosswalls, 3 ft. short of the length of the chamber, each alternately, the alternate end of each wall being tied into the outer walls, arching the whole over from wall to wall, or covering it with flags (any more convenient form might be adopted, provided the length and height of the flue was obtained)—the smoke and rarefied air from the furnace to be conveyed by an ordinary-sized flue into it at one corner, passing through it zigzag to the end, and then up the chimney, which need not be higher than the buildings around. There should be a door into it, at some convenient place, to take out the soot; and at the first time it was started it would be necessary to put in a quantity of shavings and light them, in order to start the draught; this would only be required when it was first commenced with, or after it had been a long time out of use.

"The writer conceives that, when the flue is filled with the smoke and rarefied air from the furnace, there would be a partial —and but a partial—vacuum in the flue, or that the volume of air in it would not be of equal density with the surrounding atmosphere, and that the difference in the specific gravity of the smoke and hot air in the whole flue, and the like quantity of atmosphere, would be so great that the air would rush through the furnace with great force to effect an equilibrium, thereby creating an intense draught—the great desideratum in building long chimneys, which is prevented taking place (the equilibrium) by its being rarefied by combustion in passing through the furnace.

"Suppose, after the flue was filled with smoke and rarefied air, the communication from the furnace was cut off by a damper, and another one opened for the atmosphere

* Several other more or less affected terms are applied to this part of a furnace by the ultra-chemical school of smoke-prevention patentees; such as mixing chamber and diffusing chamber, of which the term combustion chamber is perhaps the least inappropriate, although, in reality, combustion goes on more vigorously in the grate-room than anywhere else.

to pass into the flue, would there not be a very strong draught into it, intense at first, and progressively diminishing till an equilibrium was effected? The malt kiln has large flues or chambers under the perforated tiles, into which the hot air generated in the fire passes, and, without the aid of any chimney, has a strong draught.

"The baker's oven, when heated by a fire in what they designate a wagon, has a very strong draught, entirely owing to the space the smoke and hot air has to spread in, before passing to the chimney. The same oven, when heated by a fire spread on the bottom in the common way, has a very poor draught, the oven being converted into a fire-place without any hot-air chambers or large horizontal flue. The reason why the wagon plan is not in more general use, is owing to the wagon being so soon burnt out, arising from the strong draught. It is an almost universally received opinion that horizontal flues check a draught; but this, I conceive, arises from their being generally made of the same size as the flue of the chimney.

"Have not some of the recent builders of long chimneys, to supersede several smaller ones, planted them at some distance from their furnaces, and made a horizontal flue to carry all their draughts to the chimney? and when they have turned the first draught into it they have had a very strong one; but as they have added the others, the draught has progressively diminished. The width of the large chimney is made too large for one draught, consequently the atmosphere would descend the chimney and create a down-draught, diminishing the advantage of its height for one draught; but, as the rest of the draughts were put in, the down-draught would be less and less, and when all were put in, the smoke and hot air would fill the chimney to the top, having the whole benefit which its elevation is supposed to give,—demonstrating, as I conceive, that the horizontal flue, which was constructed wide for several flues to run into, is the occasion of the superior draught, when only one was put in, and not the long chimney.

"As respects the smoke when it is passing through the proposed flue, from the great space it has to pass in, it moves slowly along, though the draught is quick. From this circumstance, and the rarefaction of the air in it, he conceives it will have time to condense and fall to the bottom of the flue before it arrives at the chimney. But to render this desirable object more complete, he thinks that if the condensing water from the engine was introduced by a siphon pipe into the flue next to the furnace, and passed along its whole length in a gutter, and taken out near the chimney by another siphon pipe, the steam that would arise from the water would partly be absorbed by the floating particles of soot, and sooner fall to the bottom.

"The writer, some time ago, erected a flue, or chambers, similar to what he has described, to destroy coal tar. He set fire to a quantity of shavings in the flue, and then lighted the coal tar in the fire-place, calculating that it would burn slowly, and that the soot would all be deposited at the bottom of the flue. When ignited, it blazed most furiously, and passed through the small into the large flue with such rapidity, owing to the intense draught, and the flame was carried such a distance in, that the chamber would soon have been destroyed, being covered with flags, that he had it put out as expeditiously as possible. He then had small low arches built over the fire-place, leaving out a brick here and there, by which means he checked the draught, which was still sufficiently strong for the purpose, and not a particle of soot issued from the chimney, all being deposited at the bottom of the flue. The chimney, if it could be so called, was not more than eighteen inches high, and not more than three feet above the level of the flue from the fire-place.

(Signed) "A Constant Reader."

The writer of the foregoing letter was a well-known engineer in Manchester, and at the time of its publication, his opinions on the subject treated on, were highly valued by several of the manufacturers, who placed the matter in my hands for the purpose of investigation, and the result was the following letter addressed to the editor of the same paper:—

"The proposal of your correspondent for attaching long horizontal flues or chambers to steam-engine furnaces, if carried into effect, so far from serving as a substitute for long chimneys, would render them more than ever necessary. Nothing can be better established among practical men conversant with the subject than the fact, that every interruption or bend in the flue of a furnace, acts as a check to the draught, and where such checks or interruptions

occur, there is generally found a deposit of soot or dust, which otherwise would have found its way through the flue and out at the chimney top.

"With respect to the strong draughts generally obtained at a malt-kiln or a baker's oven, very little consideration is required to see that the draught in such cases depends upon quite a different principle to that of a steam-engine furnace. In those, the draught is, in great part, owing to the great mass of brickwork and other materials (generally substances that retain heat a long time) used in their construction, becoming heated to a considerable degree at the commencement, and from which, by the nature of the operations carried on, the heat is but slowly abstracted. Hence the velocity of the current of air passing through the furnace is accelerated in proportion to the length of the flues, or area of heated surface, and a very small chimney is therefore sufficient. Whereas, in the case of a steam engine boiler, things are very different, for here we have the fire generally surrounded by an extensive surface of iron plate, kept comparatively cool by the contained water rapidly abstracting the heat in the generation of steam. And, in order that this abstraction of the heat by the water should be as complete as possible, before the smoke is allowed to pass off into the chimney, numberless contrivances have been resorted to; as is exemplified in the multiflue boiler of Messrs. Booth and Stephenson, to the application of which to locomotive purposes, we are undoubtedly indebted for the only efficient system of economical travelling by railway.

"You must easily perceive, that with any regard to economy especially, how important it is in the generation of steam, that the smoke should leave the boiler at a comparatively low temperature; and if so, its tendency to ascend must be very small; particularly when you recollect that carbonic acid, which is one of the principal products of the combustion of coal, is considerably heavier than atmospheric air of the same temperature. Hence exists the absolute necessity of assisting the draught by the superior levity of a column of heated air, as compared to that of a similar column of the external atmosphere, the pressure of which, by a well-known hydrostatical law, is in a certain direct ratio to its perpendicular height, and is quite independent of its other dimensions.

"It requires no theoretical elucidation, and very little scientific knowledge, to understand the great difference there is in principle between the firing of a steam-engine boiler and the heating of a baker's oven. Almost any one, I should think, who pays common attention to such subjects must be aware of it; and the same may be said of a gas retort furnace, or of a brick-kiln. In these it is the mass of non-conducting matter heated, and the slow abstraction of this heat, leaving a large surplus to pass up the chimney, which is the principal cause of draught. On the contrary, in the furnace of a steam-engine boiler, the largest possible quantity of heating surface (but as regards its effects on the draught it may more properly be called cooling surface), composed of the best conducting substance, is, or ought to be, exposed to the current of hot air; consequently the main flues and chimneys of such furnaces are nearly as cool as the external atmosphere. Therefore, unless an artificial blast is used, as in the locomotives and some other high-pressure engines, the adoption of long chimneys is altogether unavoidable.

"If manufacturers who employ steam-engines were at all likely to be induced to increase so important an item of their expenditure as that of fuel, for the mere purpose of heating their chimneys—which is evidently the principle of your correspondent's scheme—it might be worth while showing him that the great desideratum of smoke burning would thereby be rendered more difficult of attainment than ever. Of this, indeed any one who admits the facts, which all must do—that for burning or preventing smoke we require an increased heat of the fire, and for increasing the heat of the fire we require an increased draught through the fire, rather than through the flue—it is only necessary to observe what takes place when a chimney is on fire, to be convinced of what I now state. In such case the draught is all in the flue instead of the fire-place, where it ought to be; and, of course, the heat is then all at the wrong end of the chimney.

"That checking the draught of a furnace by brickwork or other obstructions in the flues, may be termed a preventive of smoke, is admitted—partly by causing a deposit of soot in the flues, but principally from the smoke not being so rapidly generated. In the latter particular it bears

some resemblance to many other plans strongly recommended in your and other papers for years past, as I have no doubt many other similar plans will, for good and substantial reasons, independent of their merits or demerits, continue to be recommended for years to come. The principle of all the plans we are alluding to is the same, and equivalent to the notable expedient of keeping the furnace-door open until the fire ceases to smoke. In other words, they amount, in the generality of cases, to a complete conversion of the furnace, for a time, to the condition of a common open house-fire. Of course, under such circumstances, the prevention of much smoke becomes a very easy matter, for very little is generated; and owing to the same circumstances, I must also add, very little steam!

(Signed)
"An Advocate for Long Chimneys."

EXAMPLES OF ENGINE CHIMNEYS.

The Mayfield Experimental Chimneys.—The original design for the proportions and dimensions of this chimney were made by the author for the well-known firm of Thomas Hoyle & Sons, the eminent calico printers of Manchester, and the chimney was erected for them by the equally well-known builders, Messrs. David Bellhouse & Sons, of that city, several years ago. Its total cost, including the foundation, which was 10 ft. deep, by 15 ft. square at the bottom, very little exceeded £100.

The shaft of this chimney is octagonal in plan, about 2 ft. 10½ in. wide externally at the top, and 5 ft. at bottom. It stands on a pedestal of 8 ft. square, which together with the shaft make up a total height of 90 ft. from the ground—that being the lowest elevation allowed by the police regulations of the then borough of Manchester. The whole height from the base of the foundation being 100 ft., and about 88 ft. from the level of the fire-grate, which is the proper datum line from which all calculation respecting the draught is to be taken. The whole, excepting the stone cap and cornice, being of brickwork.

The shaft has a batter, externally of one inch to the yard, which is the usual rate, in this part of Lancashire. In the northern and hilly parts of the county—say about Preston and Oldham—a batter of one and a quarter inch to the yard is more generally used.

The work at the bottom of the shaft is 19 in. thick, and that of the top is 9 in. The shaft is entirely octagonal inside throughout down to the bottom, and externally to the top of the pedestal.

The internal capacity of the chimney, together with the short flue connecting it with the boiler, to which it is attached, is about 50 cubic yards.

The internal horizontal area of the narrowest part of the aperture at the top of the chimney is about 1,000 sq. in., which, as it was intended to make the chimney large enough for about 50 horse power, gives about 20 sq. in. area for each horse power; while, as above stated, there was about one cubic yard capacity in the chimney for the same.

Although the proportion of 20 sq. in. area of chimney aperture, for each horse power of a steam-engine, had been generally accounted in Lancashire to be "according to Boulton and Watt," neither that nor the proportion of a cubic yard of capacity per horse power was adopted from any theoretical rule or previously determined opinion, excepting that they were nearly the average of some of the best chimneys we were then well acquainted with. For, although Tredgold's rule had been published a few years previously, and was generally considered to be founded on principles pretty nearly correct, it was very evident that author had not himself sufficient knowledge of the working of steam-engines to enable him to obtain proper constants for the practical application of his own calculations, simple and admirable as the latter generally were. There only, in fact, wanted a more careful selection of data to render his formulæ highly valuable to the practical engine-maker.

The proprietors of the Mayfield Print-works—the intimate friends, disciples and patrons of the celebrated John Dalton, the great reformer of chemistry, who was at the time of these experiments, as he had been for some years previously, our constant visitor and adviser in scientific matters—were not the kind of men to be easily led astray by Tredgold's, or any other mere theoretical rules about steam-engines, however flourishing the algebra by which they might be surrounded. They had in fact wisely resolved to erect this experimental chimney for the very purpose of acquiring for themselves accurate experimental knowledge and correct practical data in all that

relates to chimneys and boilers; including also, though not at the time an essential object, a little smoke burning by the way; in all of which, not only Tredgold, but most other theoretical writers on the steam-engine, appeared to them clearly deficient.

On referring to Tredgold's rule, in his well-known work "The Steam Engine," we found him recommending what rendered his authority entirely nugatory in the matter of chimneys—namely, that "a chimney of double the size given by the rule should be built;" and, as if conscious of the great inconsistency—to say the least—of giving us this kind of instruction, he adds the following very lame reason: "because the expense," he states, "bears a small ratio to the increase of size, and it may afterwards be convenient if considerably larger than is necessary for the engine it is erected for!" Now, although Tredgold, justly or unjustly, up to that time had stood foremost in the application of high mathematical acquirements to the improvement of the steam-engine, advice of this kind necessarily demolished all confidence in his book as a scientific guide on the subject of chimneys.

The extract above quoted from Tredgold is followed up by an example in which the side of a square chimney for a 40-horse engine is calculated to be equal to 23 in. "But" he adds, "I would advise to build a chimney 33 in. square!"

The rule and the example, as given in Woolhouse's edition of Tredgold's work (Art. 275), published in 1833, after the author's death, are as follows:—

"Rule.—The area of a chimney in inches, for a low-pressure steam engine, when above 10 horse power, should be 112 times the horse power of the engine, divided by the square root of the height of the chimney in feet.

"Example.—Required the area of a chimney for an engine of 40-horse power, the height of it being 70 ft.

"In this case

$$\frac{40 \times 112}{\sqrt{70}} = \frac{4480}{8.4} = 533.2 \text{ sq. in.}$$

The square root of this is 23 in., which will be the side of a square chimney. Or, multiply 533 by 1.27, and extract the square root for the diameter of a circular one."

Now, as my present purpose is the practical one of showing how a chimney for the furnace of a steam-engine boiler ought to be built, and what are its proportions, in order best to answer the object in view, namely, the obtainment of a good draught with stability and economy—I shall, at least in the first instance, purposely waive all theoretical refinements of calculation until a rough outline of the method of proceeding be fairly established. To effect this in the most simple and direct manner, I depend far more on practice than theory, on example rather than precept—a mode of procedure analagous to that of teaching any common mechanical trade, which I have occasionally resorted to on other subjects, with a certain measure of success.

In Weale's large edition of "Tredgold on the Steam Engine," in 4 quarto volumes, 1852, edited up to page 116, by the late Professor James Hann, of King's College, and thence up to page 308 by the present writer, I gave, in the notes, some examples of these calculations for chimneys adapted to practical data first discovered—at least, collected and arranged—by the late Joshua Milne, Esq., of Shaw, near Oldham, some years prior to the first publication of Tredgold's work, in which the area of the chimney is expressed in square feet instead of inches. Adapting Tredgold's rule to Mr. Milne's data, it only requires the constant multiplier 112 to be substituted by 280, and the calculation in the above case will then stand as follows:

$$\frac{40 \times 280}{\sqrt{70}} = \frac{11,200}{8.4} = 1,333 \text{ sq. in.}$$

instead of 533; a result nearly three times as much as that obtained by Tredgold, and the square root of which is 36½ in. for the side of the square chimney, instead of 23 in., as before. That is to say, about 3 ft. and 2 ft. square, respectively.

It is obviously much better to simplify such practical rules as these, by using the same denomination for both dimensions, the height and the area, or the diameter of the chimney. And since the large expensive edition of Tredgold as above referred to, as published by Weale, which has been until recently in a great measure a sealed book to many practical men, is now in the hands of a more liberal and enterprising publisher, who has made it more accessible by reducing it to less than one-half its former price, we have some pleasure in promoting its utility in the same direction, by adding here, as was partially attempted in that work, a formula which includes Milne's constant, for ready computation by instrumental in-

spection, as well as by common arithmetic, so that every intelligent operative who honors these pages by his perusal and carries a slide-rule, has always at hand a ready mode of verifying the truth of our statements, and comparing them with those of Tredgold, or any other authority.

SLIDE-RULE FORMULA FOR HORSE POWER OF CHIMNEYS.

A	Area in inches	Constants { Tredgold 112 ; Milne ... 280
D	sq. root of height in ft.	Nom H. Power.

Tredgold's example for a 40-horse engine before referred to—

A	Area=533 in.	Tredgold's Cons.=112
D	$\sqrt{70}$=8.4 ft.	Nom H. P. = 40

Milne's Const. = 280

Nom. H. P. = 16

In his arithmetical rule, instead of a multiplier, Milne used a divisor for a constant number, and was in words as follows :—

RULE.—Multiply the square root of the height of the chimney in feet, by the square of its internal diameter at its top or narrowest part also in feet, and half the product will be the nominal horse-power that the chimney is equal to.

Taking the same example as before, it is by arithmetic—

$$\frac{\sqrt{70} \times (1\text{ft. }11\text{ in., or) }1\ 92^2}{\text{divided by 2}} = \frac{8.4 \times 3.68}{2} = 15\ 45$$

horse power ; and by the slide rule it is *approximately*—

A	Diam.^{2}=3.68	Cons. divisor 2
D	$\sqrt{\text{height}}$=8.4	Horse power = 15.4

After we first published these chimney rules, at the desire of Mr. Milne, several years ago, apprising him at the time of the wide difference between his and Tredgold's results, we soon found, and he admitted, that a somewhat smaller proportion of chimney area would be more nearly in accordance with the general practice throughout the country, more especially where a better quality of coal was burned than that ordinarily used at the factories in Oldham, where, from the peculiar quality of the cotton manufacture carried on there—spinning coarse cotton, waste, and shoddy—a larger measure of work was usually allowed for a nominal horse power than elsewhere. In fact, two indicated horse-power for one nominal, was then the regular Oldham measure for steam-engines.

If we take Tredgold's advice, and give double the area of chimney-top obtained by his rule, then the adoption of $1\frac{1}{2}$ instead of 2 for a constant divisor will give that result which we may conveniently call the actual instead of the nominal, or Oldham horse power, which will still, as it ought, be considerably in excess of the indicated power of steam-engines in general.

In illustration of this, take—

Example 2.—Required the number of horse power most suitable in connection with the experimental chimney at Mayfield already described; the height above the level of the fire-bars being 88 ft., and the inside diameter at the top 2 ft. $10\frac{1}{2}$ in.

SOLUTION BY SLIDE-RULE.

(*Slide inverted as before.*)

A	Diam. 2 ft. $10\frac{1}{2}$ in.^{2}=2.87^2=8.26
D	$\sqrt{\text{ht. (88)}}$ = 9.38

New Const. = 1.15

Answer 51 H. P.

Example 3.—Another new chimney erected the same year, in the same works (Thomas Hoyle & Sons), was $3\frac{1}{2}$ ft. diameter by 40 yards high. Required the horse power it is equal to.

SOLUTION.

A	Diam. $3\frac{1}{2}$ ft.^{2}=$12\frac{1}{4}$	Const. number $1\frac{1}{4}$
D	$\sqrt{\text{ht. (120)}}$=11	Horse power 90

The chimney in this example (3) was erected in November of the same year, and by the same builder as that in Example 2. It was built with similar materials in the same manner like the preceding chimney. The shaft was octagonal, but higher in proportion to its area than the former, for the purpose of carrying away the smoke from contact with some adjacent buildings, and the cost was about double that of the experimental chimney. By which it will be seen that we had arrived at a fair average cost of chimney-building in proportion to the power capable of being produced in that way, so far as chimneys of this character, and from 30 to 40 yards high, are concerned—namely, about £2 per horse power.

The very many practical tests of various kinds that were applied to these two chimneys, during several successsive years, such

as finding that the second chimney was equally applicable to two as the first or experimental chimney was to one boiler of similar size, not much over or under 45 or 50 horse each, convinced us that we had approximated near to the data we were in quest of.

The Duckinfield Bleach Works, Chimney and Furnaces.—The subject of our next example in chimney building served still further to corroborate our Mayfield experiments in all respects except as to cost, which of course greatly diminished as the scale of our operations became larger.

This chimney was erected early in the spring of the year following the completion of those last named, at Messrs. Hoyle & Sons' New Bleach Works, then erecting at Sandy Lane, between Duckinfield and Staleybridge.

In the planning of the chimney and flues, and furnishing the designs, with all their details, and four large boilers, for which the writer was more especially engaged, and which were expected to furnish from 200 to 300 horse power of steam, we had the valuable assistance of Mr. John Graham,* afterwards a member of the firm, and whose eminent talents as a scientific and practical chemist are generally known—as we also previously had the cordial assistance, general concurrence and approval of the late Mr. Alfred Binyon, the then managing partner.

Example 4.—The Duckinfield Bleach Works chimney was made 45 yards high by 6 ft. inside diameter at the top. Required the horse power it is equal to.

SOLUTION.

A	Diam. 6 ft. $\|^2 = 36$	New constant $= 1\frac{1}{2}$
D	$\sqrt{\text{ht.}\ (135\ \text{ft.})} = 11.6$	Horse power $= 278$

Milne's Const. 2
" " 208

The above slide-rule solution for the power of this chimney gives two answers to the question—namely, 278 and 208 horse power, respectively, according as the new constant $1\frac{1}{2}$, or Milne's old constant 2, are used as gauge points. In this case the latter was preferred, as giving the most correct result, by reason of the kind of fuel intended to be consumed being of the same or similar inferior quality to that already referred to as being in general use within the parish of Oldham, to which these works were nearly adjoining. Facility in obtaining this cheap fuel—known as "burgey" and "slack"—being one of the chief reasons for erecting the works in this particular locality.

THE EXPERIMENTAL BOILERS.

In the collection of data for steam-engine chimneys, it would be a great omission to leave out the particular dimensions of the boiler, to cause the efficient working of which is, in fact, the only profitable work the chimney has to do.

The boiler, for which the Mayfield experimental chimney was erected, was designed by the writer, as was also the chimney, as already stated, specially for experimental purposes, in acquiring all practical information on the subject previous to commencing the construction of Messrs. Hoyle & Sons' new Bleaching and Calico-printing Works at Duckinfield, near Staleybridge. For this purpose I did not hesitate to recommend the plainest and simplest form of boiler that can be conceived—namely, a plain cylinder, laid horizontally, or nearly so, with the fire to go underneath it at one end, and out to the chimney at the other, which may now be described.

This experimental boiler was of the "direct draught" kind, that is, without return flues, and this one had no flues of any kind, either inside or out. The boiler and chimney were, therefore both of the simplest possible kind, and for that reason, made mutual tests of their respective capabilities through a long series of very accurate experiments relative to economy of fuel, as well as to the efficiency of various methods of smoke prevention, or smoke burning, as it was then popularly termed, and other matters of interest to the proprietors. Improvments in smoke prevention especially were freely invited from all quarters, and this was the boiler at which very many different plans for the purpose were tried.

This kind of boiler was fully described in the author's "Essay on the Boilers of Steam Engines" (1839), and the principal dimensions of this one, as there given, need only

* See a valuable paper by this gentleman in vol. xv. of the "Transactions of the Literary and Philosophical Society of Manchester," for the years 1857–8. A portion of it was also republished in the "Engineer" newspaper for March 12, 1858, which gave an account of a series of evaporating experiments, made for the purpose of testing the economy of fuel and management effected at these boilers and furnaces through a series of successive years, which will well repay perusal, and will be further adverted to in a subsequent part or appendix to this work.

be shortly referred to here. It was in shape cylindrical, and fully equal to 30 horse power, being 33½ ft. long by 5½ diameter, and "set up," or rather hung, by means of cast-iron brackets riveted to the sides, and resting on the side walls of the furnace, so that the whole of the lower half of its convex surface, about 32 square yards, was exposed to the direct action of the fire and flame.

The fire-grate, placed about 22 in. below the bottom of the boiler, was 5½ ft. square, or equal to about 30 sq. ft. in area, and was composed of one length of fire-bars, each 1¾ in. thick on the face, with air-spaces of $\frac{5}{16}$ to $\frac{3}{8}$ of an inch wide between them.

This boiler supplied steam to an old Boulton and Watt condensing engine of 16-horse power, by Messrs. Sherratt, of Salford, loaded so as to require seldom less than 24 cubic feet of water to be evaporated per hour at a pressure of exactly 4 lbs. per sq. in. It also supplied steam for heating drying cylinders, for boiling water, and for a great variety of other purposes, amounting at times to nearly as much as the engine required itself. The least average evaporation for a whole day together was 33, and the greatest 45 cubic feet per hour. The lower amount was, of course, obtained at the most economical rate, namely, at about 6 lbs. of water evaporated for each pound of common coal burned. It was, therefore, considered to be full 30-horse power. A cubic foot of water evaporated per hour being generally considered amply sufficient to supply steam for each horse power (nominal) of a Boulton and Watt or low-pressure engine in good order, however it might be at times overloaded.

Although this evaporation of a cubic foot, or a little over six imperial gallons of water, of 10 lbs. each, is what boilermakers have universally, and practical engineers commonly, agreed to consider nominally a boiler horse power, there is no doubt, however, that the same weight of water, as steam, at a higher pressure can easily be, and is frequently, made to work two or three indicated horse power in a modern steam-engine, accordingly as the latter is arranged to work to a greater or less extent expansively.

This boiler was made of Low Moor iron $\frac{5}{16}$ in. thick, except the bottom row of plates, which were ¾ in. and the flat ends $\frac{7}{16}$, by Mr. Fairbairn, of Manchester, who had just previously commenced the boiler-making business, and was then a staunch advocate for introducing the long Cornish high-pressure boiler, with its one large internal furnace-flue, and single furnace-grate. Instead of that kind of boiler, now much less used, except in Wales and Cornwall, I persisted in advising the simple and elementary form of boiler now described. It was also suspended by bracket flanges in the cheap and simple manner above mentioned, in accordance with the universal dogma of its strictly utilitarian owners, which in this, as in all other business matters connected with the works, was never lost sight of for a moment,—in order that any alterations or improvements that might be found expedient, either in the construction of the boiler, or erection of the brick-work, might be in the shape of additions merely, and therefor capable of being separately proved, both as to first cost and utility, and also that our experiments might be carried on for a sufficient length of time, without the usual liability to interruption from the necessity of cleaning out of flues or otherwise.

The last-mentioned particular in the erection of this boiler was of considerable importance in thus attaining the main object we had in view, as well as in accomplishing another object greatly desired by the benevolent proprietors of the works, that of doing away with the degrading practice of sweeping out the flues by means of men, or rather boys, crawling through them.

Trifling as a small matter of this kind may appear to some, it is important to show that, in this instance at least, it was attended by considerable economy. Cast-iron lugs or brackets, with broad flanges, were riveted along each side of the boiler, a little above the intended surface level of the water, and these brackets rested on the tops of the two vertical side walls of the furnace and flame-bed. The boiler thus suspended between the two side walls was then adjusted, not quite horizontally, but slightly inclined, with a fall of about 8 in. towards the front end, so that a greater proportion of the water was brought immediately over the fire-grate.

This arrangement of the flame-bed and seating, or side walls, of the boiler, formed a chamber or receptacle, large enough to hold all the flue-dust and dirt that could be found from the use of any kind of coal whatever, for a considerable time. In fact,

although the boiler was every day at work, the flame-bed did not require any cleaning out, even at the end of nearly two years,—when, as an opportunity occurred, several cart-loads of flue-dust were removed from under the boiler at one time. The occasion of having this operation performed, discovered to us a circumstance, which is sometimes the cause of great disappointment to the expectations of parties who, for the first time, have boilers erected on this direct draught plan, which requires an explana- in this place.

At all direct draught boilers, it is usual to have, and highly necessary that there should be, two or more transverse "check" or flame-bridges, in addition to the ordinary fire-bridge, carried up to within 6 or 7 in. of the boiler bottom; but in this case, there was, in the first instance, only one of these additional bridges, and the man employed to get out the flue-dust had, in order to make an easier passage for himself, removed two or three courses of brick-work from the top of the flame-bridge, and neglected to replace them again. The consequence was, that on the boiler commencing work again, a clear loss of 15 per cent. in fuel was detected immediately, besides the overheating of the damper-plate and brickwork of the chimney entrance, which evils were, of course, quickly rectified by replacing the brickwork. Although no very great nicety is required in adjusting the height of these flame-bridges, and an inch or two higher or lower may not make much difference in the economy of fuel; but the extent of 8 or 9 in. in depth of the air passage over them, when there is already a depth of the same extent in the throat area over the furnace-bridge, will at any time cause an exorbitant waste of fuel.

The fact of an error of this kind, which is very liable to be passed over unnoticed by ordinary bricklayers and boiler-setters, unless very carefully supervised, has been frequently the occasion of much error in experiments on the economy of fuel. It is all the more necessary to mention the above circumstances here, because, since my description of the direct draught method of setting boilers was first published in 1837-8, I have occasionally had complaints from parties who had been induced to adopt the direct plan, but had not succeeded in realizing any moderate measure of economy therefrom, and had, in consequence, too readily, or without sufficient examination, given it up, and returned again to the wheel-draught, narrow flue system, with its little army of chimney-sweeps, boiler-menders, and laborers, and all its other disagreeable and expensive accompaniments of Sunday work, over-work, and night-work. It is, however, but fair to state that extreme cases of this kind have been mostly confined to the South of England and the metropolis, where the extravagant use of flaming Newcastle or Hartley coal, with very much unnecessary stoking of the fires, is still continued. These results have been helped not a little, perhaps, by the prognostications of many of the old school of bricklayers, that the direct draught plan would "send all the heat up the chimney," and who too often testify their sincerity in such a belief by taking especial care to build their chimneys and flues very narrow and very crooked.

The prejudices of some of the attendants of engines in London in favor of much stoking and hard firing, which is literally working hard at wasting coal, are difficult to account for, especially when found among persons not notorious for working hard at anything else; but a residence among them of any one whose business is to save fuel, will very soon convince him of the fact. Hence a more careful attention to the condition of all the bridges under a boiler is a necessity which ought never to be neglected.

INSTRUCTIONS TO STOKERS.

1. Engineers and firemen who would keep steam with economy, should do with as little stoking or stirring of the fire as possible, if any. In order to do so, they should see before starting that the furnace is properly constructed for the purpose, and large enough for the quantity of steam required. The fire-grate should have about 1 sq. ft. of effective fire-bar surface for each nominal horse-power of the engine, or for each cubic foot of water required to be boiled away per hour. The fire-bars may be from $\frac{1}{2}$ to $\frac{3}{4}$ in. thick on the face with $\frac{1}{4}$ to $\frac{3}{8}$-in. draught spaces between them, and with joggles to keep them asunder nearly the whole depth of the bar. The boiler should have, at least, 8 or 10 sq. ft. of heating surface per horse, and the chimney should be of sufficient capacity to create a draught into the furnace equal to the pressure of a column of water $\frac{3}{8}$ to $\frac{5}{8}$ in. deep, when the damper is set wide open.

2. In firing, spread the large and small coals (equally mixed) on all parts of the grate, thicker at the back of the grate near the bridge than at the front, because the draught is there the strongest, and the coals burn away the quickest.

3. The fire should never be less than about 3 or 4 inches thick in the middle of its length, 2 or 3 in. in front, and 6 or 8 in. at the back of the grate. In no case should the fire exceed double the depth here stated; and never more than two-thirds of the fire-grate should be entirely covered with fresh coals at one time.

4. If a regularly uniform supply of steam is required and the damper quite up, the quantity of fuel on the grate may be gradually increased; but when an increasing quantity of steam is wanted, the average thickness or quantity of fuel on the grate must not then be increased, but ought rather to be diminished, and supplied by smaller quantities at a time, and more frequently. So soon, however, as the supply of steam exceeds the demand, the coal must again be supplied by larger quantities at a time, regularly increasing the quantity of fuel in the grate as before. On the other hand, when a diminished supply of steam is required, close the damper a little, and take the opportunity of levelling the fire or cleaning the fire-bars, doing one-half of the grate at a time.

5. A steam-engine furnace worked in this way will make very little smoke; or, if any, it may be prevented when desirable by opening the fire-door 2 or 3 in. for 1 or 2 min. after each firing. Bearing in mind that the production of steam is commonly lessened by doing so, but so is the consumption of the fuel.

6. Stokers should understand that they are not to make a business of "stoking," but to leave it off entirely, excepting only when preparing to clear out the grate from clinkers and rubbish, which requires to be done generally three or four times a day with average qualities of coal; convenient times being chosen for the purpose when there is the least demand for steam.

7. A fireman's business is, first, to see, before the fire-door is opened, that no coal is left in the heap ready for going on bigger than a man's fist; and that very small coal or slack is wetted, or at least damp, as well as a little water always in the ash-pit. Then begin by charging into the farther end of the furnace, reaching to about one-third the length of the grate from the bridge, as rapidly as possible, from a dozen to twenty or thirty spadefuls of coals, until they form a bank reaching nearly or quite up to the top of the bridge, and then shut the fire-door, until the other fires, if there are any, are served in the same way.

8. In firing up, throw the coals over the rest of the grate by scattering them evenly from side to side, but thinner at the front, near the dead plate, than at the middle or back. In this manner keep the fuel moderately thick and level across the bars, but always thicker at the back than the front, not by pushing the fire in, but by throwing the coals on exactly where they are wanted.

9. Never for a moment leave any portion of the bars uncovered, which must be prevented by throwing or pitching a spadeful of coals right into any hollow or thin place that appears; and always remember that three or four spadefuls thrown quickly one on the top of the other, will make no more smoke than one, and generally less. But all depends on doing it quickly; that being the main, if not the only point in which freedom from smoke and economy of fuel agree. Some firemen only put on three spadefuls, while another can put on four, and make 20 per cent. more steam in the same time by doing it.

10. In replenishing the fire, take every opportunity of keeping up the bank of fuel at the bridge, by re-charging it, one side at a time. Whenever this bank is burnt entirely through, or low, and also when the fire is in a low state generally, take the rake and draw back the half-burnt fuel, 12 or 18 in. from the bridge, and re-charge fresh coal into its place, upon the bare fire-bars as at first.

11. An engine fire tended in this way will consume its own smoke without difficulty, simply by admitting a very moderate supply of air (which for safety to the boiler should be heated) at the bridge, this being a more certain and economical mode of prevention than that of diluting the smoke by the admission of much cold air at the fire-doors.

12. It may be set down as an axiom that a steam-engine chimney cannot be too large, if only provided with a damper, although ninety-nine in one hundred, at the present time, are decidedly too small. They are unable to create a sufficient draught of air through the furnace, conse-

quently a smoky flame is produced, instead of a flame with little or no smoke.

13. Want of chimney draught is a defect which no smoke-consuming furnace in the world can remedy, whether using hot air or cold, unless by the application of an artificial blast, which commonly costs as much to work as the heat it creates is worth.

14. It being impossible to consume smoke without great heat, which requires a good draught, and difficult to get a good draught without a large chimney, I here set down a table of chimney proportions, which have been practically proved to answer well with the inferior steam coal of the manufacturing and midland districts for many years past. It is true that somewhat smaller dimensions might serve where the extravagant use of Newcastle coal is still continued, as in London; but even here those dimensions and proportions ought to be adhered to, because of the constant tendency to increase the engine and boiler power, while the same brick chimney remains. For similar reasons I commence with a chimney suitable for a 10-horse boiler, although a 5, or even a 2-horse engine only, may be required.

Height of Chimney.	Inside Diameter at Top.	Nominal Horse-power of Boiler.
20 yards.....	1 ft. 6 in.	10
25 "	1 " 8 "	12
30 "	1 "10 "	16
33 "	2 " 0 "	20
35 "	2 " 6 "	30
40 "	3 " 0 "	50
40 "	3 " 6 "	70
40 "	4 " 0 "	90
45 "	4 " 6 "	120
50 "	5 " 0 "	160
55 "	5 " 6 "	200
60 "	6 " 0 "	250

15. A common low-pressure condensing engine is usually overloaded when it has less than 25 circular in. in the cylinder for each nominal horse-power; and a high-pressure non-condensing engine ought to have from 10 to 12½, and to be worked at double the effective pressure, at the least, of the former,—say 30 to 40 lbs. per square inch in the boiler.

ON THE DURABILITY AND PRESERVATION OF IRON SHIPS, AND ON RIVETED JOINTS.

By Sir WILLIAM FAIRBAIRN, Bart., F.R.S.

From "Iron."

The disaster which happened to the Megœra shows the need of constant inspection of all iron structures. That vessel was built by the author in 1849, and, in his opinion, would have been perfectly sound at the present time if her interior had been freely open to inspection, and if such inspection had been regularly carried out. Some years ago an alarming report was circulated as to the corrosion of the Menai Bridge. The author, on that occasion, visited the bridge, and found that no corrosion had taken place; careful attention to proper means of prevention having been sufficient to preserve the structure. As regards steamships, the value of periodical inspection has been long proved; and it is to be hoped that the Admiralty and private shipowners will soon recognize the extreme importance of similar inspections of all iron vessels.

As respects riveted joints, machine-riveting gives (in the author's opinion) far greater security to the work than hand-riveting, since, in machine-riveting, there is much greater certainty of the holes being properly filled by the rivet. The rate at which riveting can be done is sixteen rivets per minute with a lever riveting machine, ten rivets per minute with a steam riveting machine, and 0.66 rivet per minute when the riveting is done by hand. In every respect, therefore, the advantage is on the side of the machine.

In 1860, the author communicated to the Royal Society a series of experiments on the strength of riveted joints. Those experiments showed that, taking the strength of a solid plate at 100, the strength of an equal width of riveted joint would be 70 if the joint were double riveted, and 56 if the joint were single riveted; in other words, 30 per cent. of strength is lost in a double riveted joint, and 44 per cent. in a single riveted joint.

Since that time it has appeared to some

engineers that the process of punching was injurious to the plates, and in many cases recourse had been had to drilling to form the holes for the rivets.

On this point the author is completely of opinion that, with *good* iron, no sensible injury can possibly result to the plates from punching the rivet holes; on the other hand, with rigid and bad plates, the plate would undoubtedly crack between the rivet holes, and would therefore have to be discarded, a result rather to be hoped for than to be deprecated. To the author's mind it is one of the distinct advantages of the punching process, that it thus tests the quality of the iron which is operated on.

It had been found in certain cases that the rivets sheared across with a less force when in drilled than when in punched holes, and this had been attributed to the sharpness of the edges of the drilled holes. This point seemed to require investigation, and experiments to elucidate the matter have therefore been made.

The theory that the sharp edges of drilled holes induced a cutting action, which diminished the strength of the rivets, suggested to Colonel Inglis, R. E., to try whether a greater resistance in the joint could be obtained by purposely rounding off the edges of the rivet holes. Some experiments were therefore made by Mr. Kirkaldy for Colonel Inglis. The result of these appeared to be that the resistance of the rivet was increased 10 per cent. by this rounding of the edges of the rivet holes.

The following table is the summary of results obtained by the author:—

Number of Experiment.	Diameter of Rivet.	Sectional area of Rivet.	Shearing resistance of Rivet.	Shearing resistance per square Inch.	Elongation of Joint.	Remarks.
	Inch decimals.	Sq. Inch. decimals.	Tons.	Tons.	Inch decimals.	
1.	.84	.554	10.819	19.528	.190	Single shear, punched holes, machine riveted.
2.	.82	.528	10.879	20.606	.272	Single shear, punched holes, hand riveted.
3.	.84	.554	10.257	18.514	168	Single shear, drilled holes, machine riveted
4.	.82	.528	10.739	20 339	.190	Single shear, drilled holes, hand riveted.
5.	.82	.554	11.221	20.254	.270	Single shear, drilled, edges of plates rounded, machine riveted.
6.	.82	.528	11 192	21.197	.240	Single shear, punched and countersunk, hand riveted.
7.	.84	.554	10.850	19.584	.160	Single shear, drilled and countersunk, machine riveted.
8.	.82	.528	11.234	21.276	.288	Single shear, drilled, edges rounded, countersunk, hand riveted.
9.	.82	.528	23.375	44 270	.340	Double shear, punched, hand riveted.
10.	.82	.528	20.684	59.174	.232	Double shear, drilled, hand riveted.
11.	.82	.528	24.313	46.047	.482	Double shear, drilled, edges rounded, hand riveted.
12.	.82	.528	26.464	50.121	....*	Double shear, drilled, edges rounded and countersunk, hand riveted.

The general conclusions drawn by the author from these experiments are as follows:—

1. Joints, with drilled holes, are weaker, and elongate less before fracture, than joints with punched holes. The average of four experiments in joints with drilled holes, compared with the average of four experiments in joints with punched holes, shows that the rivets in the former are 1.36 ton per square inch, or 6½ per cent., weaker than the rivets in the latter. The elongation is also 26 per cent. less with drilled than with punched holes.

2. Hand-riveted joints are somewhat stronger than machine-riveted joints.

The mean of three experiments on hand-riveted joints, compared with the mean of three experiments on machine-riveted joints, shows an excess of shearing resistance in the rivets in the hand-riveted joints, amounting to 1.495 ton per square inch, or, 7¼ per cent. The hand-riveted joint also elongates 26 per cent. more than the machine-riveted joints.

3. There is a decided increase in the strength of the rivet when the edges of the rivet holes are rounded, so as to diminish their cutting action.

The mean of three experiments on joints

*This rivet did not shear. The plate broke away.

of rounded holes, compared with the mean of three experiments on joints with unrounded punched holes, and with the mean of three experiments on joints with unrounded drilled holes, gives the following results :—

		Shearing resistance of rivet.
Rounded holes		21.517 tons per sq. in.
Unrounded holes.	punched	20.953 " "
	drilled	19.228 " "

This shows that the joint with rounded holes is, as regards the resistance of the rivet, 12 per cent. stronger than the joint with drilled holes, but only $2\frac{3}{4}$ per cent. stronger than the joint with punched holes.

As regards the apparent superiority of hand-riveting as compared with machine-riveting, this is due to the fact that in hand-riveted joints the rivet is slightly hardened by being hammered after it is cold. In small experimental joints hand-riveting has, therefore, a slight advantage in point of strength; but the defects of hand-riveting are not likely to be exhibited in experiments on a small scale.

These experiments seem conclusive as to the inferiority of joints with drilled holes; and the author must reiterate his conviction that the force used in punching plates is a practical test of their quality of great importance, since it tends to prevent the use of inferior iron.

A riveted joint may give way in three different modes :—1. By the tearing of the plates from the rivet holes to the edges of the plates. 2. By the tearing of the plates from rivet hole to rivet hole. 3. By the shearing of the rivet.

When the plate gives way by tearing from the rivet hole to the edge of the plate, a bending stress is induced in the part of the plate in front of the rivet. The amount of that bending stress is approximately estimated, and a rule found for the distance of the rivet hole from the edge of the plate.

When the plate gives way by tearing from rivet hole to rivet hole, it is commonly assumed that the stress on the part of the plate between the rivets is a uniformly distributed stress. This is not strightly correct. The want of uniformity of stress will cause the plate to give way with a lower average intensity of stress than that which corresponds to the ultimate resistance of the plate to tension. How much the plate may be weakened by the want of uniformity in the distribution of the stress it is impossible to calculate.

Probably the loss of strength due to this cause is, in ductile plates, very small; but this weakening may, nevertheless, account, in part, for the apparent loss of strength of the plates at joints, as compared with the same plates broken in an unperforated condition. This loss of strength has been hitherto ascribed entirely to injury done to the plates in the punching process.

When the rivet gives way by shearing, the stress in the section is also not uniform. In consequence of the great deformation of the rivet before fracture, it is subjected to bending as well as to shearing action. The friction between the plates induced by the contraction of the rivets in cooling has been supposed sometimes to add to the apparent resistance of the rivet to shearing. So considerable a displacement of the plates, however, takes place before ultimate fracture, and the deformation of the rivets is so great that it can hardly be supposed that they exert any tension whilst holding the plates together at the moment of fracture. The fracture should therefore be entirely neglected in estimating the ultimate resistance of riveted joints.

PROFESSIONAL TRAINING FOR ENGINEERS.

From "The Engineer."

Practice in the field, and diligent atttendance upon works of a professional character at the commencement, continuation, and termination, are to the intended engineer what the hospital curriculum is to the young surgeon. He there sees and handles the materials with which he has to deal in the future. He learns by observation and assiduity the proper treatment to be adopted in particular instances, and the technical means by which difficulties of a serious nature are successfully grappled with and surmounted. In either case the end to be attained is the same, whether the strain is applied to the human frame or to the component parts of some complicated piece of mechanism or gigantic work of construction. A surgeon who had never

witnessed an operation could have no more idea of the amputation of a limb, than an engineer of the driving of a locomotive, who had never seen the machine except in a picture. There is, in every profession, a certain knowledge, an especial description of information, a teaching *sui generis*, which cannot be obtained from books, from study or reflection, or supplied by even the inventive faculties of man. It is not every man who, when the opportunity is placed before him, is able to avail himself of it—at any rate to the fullest extent, in acquiring this essential knowledge, which may be termed practical information. Many have no taste for it, or at least prefer the study of the more theoretical details. They would rather exhaust the calculus in determining the pressures upon the different portions of a retaining wall than go and build one, and there is very little doubt that they would be infinitely better adapted for the former than the latter task. It must not be supposed that we undervalue theory or the study of mathematics, so indispensable to an engineer. But the engineer who carries theory to an extreme becomes a mere bookworm, a paper engineer in fact, and is not a bit better than his brother who proceeds in the opposite track with practice, and is ready to solve any and every problem by the "golden rule of thumb." If the latter can by any means bring in a little theory to aid him he will always get the better of the former, because of all other professions that of an engineer is, on the whole, a practical one. It is a profession in which men are judged by their works; faith counts but little.

Within the last fifteen or twenty years a marked change has taken place in the education and training of engineers. It cannot be denied that the progress of the times, the introduction of railways, the employment of comparatively untried materials, respecting whose powers of resistance very little was known, and the erection of engineering structures of a novel form and on a scale of magnitude hitherto unattempted, demanded a radical alteration in this respect. One of the principal reasons necessitating the change was that under the circumstances precedent was wanting. Engineers had nothing to fall back upon. Previous practice and experience became a blank. They could supply nothing in the way of theoretical or practical information which would bear the enormous extension required of it. There was no bridge to serve as pattern for that over the Straits of Menai, and the study of the whole subject, with the aid of the mathematician and the experimentalist, became an absolute necessity. Thus a particular class of investigations, and consequently a knowledge, for the future, of those investigations and their results, were forced upon engineers, and in making themselves acquainted with these results and others of a kindred character, their education was considerably improved thereby, and its tone raised. But, in spite of the advantages which have undoubtedly accrued to the profession, owing to the altered conditions now prevailing, it is quite possible to err in the opposite extreme; and a careful consideration of the manner in which large numbers of young engineers are being now educated and trained, will, we think, tend to prove that the error alluded to is very frequently committed. As a rule, if a man wishes to learn a trade he associates himself with another who has already learned that trade, has practised it, and is at the time of the association earning his bread by it—living by it, in a word. If one wished a boy to learn the business of a butcher, one would hardly apprentice him to a shoemaker. Yet this is not one jot more absurd than to expect a young man to learn the business of an engineer by sending him for three years to a college. It will be said that at the college he learns at least the theory of his future profession, and also studies various scientific subjects intimately connected therewith. This is true, and no one for a moment would underrate the value of the education so obtained, were it not for the attendant evils, which are serious.

Were it generally understood that the college training was restricted to what it really is, viz., the imparting of such theoretical knowledge as would fit the student at the end of his course to enter an engineer's office, and learn the duties of the profession—not in a collegiate, but in a professional manner—one of the errors commonly indulged in would be rectified. It is generally supposed that a three years' college course in engineering is all-sufficing, and that the student who has completed the term, and obtained a diploma or certificate, is regularly qualified as an assistant engineer. No greater delusion can be indulged in. He knows absolutely nothing

of the routine of an office, nor of the professional manner in which things are done, to use a common phrase. It is true that designs are prepared, specifications, estimates, and quantities got out by students with great care and minuteness. But the designs are never executed, the estimates and quantities never submitted to the crucial test—that of a contractor, and the specifications are in every sense dead letters. The difference between any designs, specifications, and estimates of a professional character, being prepared at a school or college and in the office of an engineer, is, that all the responsibility which attends the one is wanting in the other. Briefly, the one is a sham, the other is a reality.

It might reasonably be imagined that anyone desiring to learn a business or profession would devote more time to that object than to others, which, although bearing upon it, and likely to prove of future value, are not of a strictly professional nature. But with respect to the engineering profession, the contrary is often the case. From three to six of theory to one of practice is about the ratio, although sometimes the equivalent of the latter becomes cipher. One of the evils arising from the prolonged theoretical curriculum prescribed at colleges, is that when the student, in order to obtain a practical knowledge of his business, enters the office of an engineer, his stay there is too short to enable him to benefit by the advantages which would be otherwise open to him. In the first place, the state of the works under the superintendence of the engineer, and his general practice, cannot be regulated, so as to suit the requirements of any young man who desires to benefit by pupilage of one or two years. Again, it is of little use to take a student from his theoretical studies, and pitchfork him into an extensive work, among a chaos of timbers, portable engines, excavations, and the whole general *melee* of a contractor's plant. He may after a time understand what is going on, he may get an idea, but little more, of the continuation of a work of the commencement of which he knows nothing, and of the termination of which he will be equally ignorant. The same method is required in the professional as in the educational training of a young engineer. The one he obtains thoroughly at a school or college, but the other it is impossible for him to acquire, unless he spend at least the same amount of time in the actual discharge of duties, which he will have eventually to fulfil almost unassisted. The most valuable kind of practice which a young engineer can obtain, is to be engaged on a work from the commencement, to assist in preparing the drawings, specifications, estimates, and quantities, and then to witness the work carried out, and if possible completed. The work need not be on a scale of great magnitude. On the contrary, if of moderate extent so much the better, as it will enable attention to be paid to all the details. It is in the knowledge of the actual details of work that theoretical men are so weak. The most important point in connection with the practical training we have mentioned, is altogether lost in the system which crams a man for three years with theory and then sends him into the office of either a civil or mechanical engineer to learn his profession in about a fourth of that time. This point is the connection between theory and practice, which is altogether wanting. There is no connection, no sequence whatever between the designs prepared in a college, and the work the student may see afterwards with an engineer. As a means of education, the various schools and colleges with especial technical classes are invaluable; but are not equally valuable for professional training, and they will never be able to turn out practical engineers, who are becoming scarcer every day. The fallacy to be avoided is to imagine that the scholastic or collegiate education renders unnecessary any future professional training whatever.

When a man says, "I wish to make my son an engineer," the natural and common sense reply is, "Then article him to an engineer." In fact, the system pursued under the old *régime* is still the correct one, with the exception that the time of apprenticeship or pupilage should be shortened, and a portion of it spent in acquiring the education now indispensable to an engineer. The mistake committed at the present day, is in substituting a different and a completely theoretical for a practical training, whereas the proper plan to adopt is to retain, in any case, the practical training, but add to it the educational. It is not by taking away the practice, but by adding the theory, that a man becomes a competent and qualified engineer at the present day. It is impossible to deny that there is just now a strong tendency to substitute theory for practice in the

training of our engineers, and it will be some time before the error becomes manifest. We are not alone in this opinion. Some eminent authorities, good theoretical men themselves, have acknowledged that a considerable portion of the time spent in a school or college is, we will not say wasted, but devoted to subjects of no practical use whatever to an engineer. Moreover, the study of some subjects with which an engineer should undoubtedly have some acquaintance is pushed too far, to the sacrifice of much valuable time and labor. It is no doubt indispensable that a professional man should possess a competent knowledge of geology, but we submit that it is time and energy wasted for him to pursue the subject to the same extent as a professed geologist. However interesting to the latter, and cognate to his vocation, it may be to be able to demonstrate that the fossil remains of some antediluvian reptile are to be found in a certain situation, the presumable proof of the circumstance does not bear upon practical engineering. It is, in our opinion, better for a young engineer to know how to hoop, shoe, and drive a pile, than to be able to calculate to an ounce—were the calculation possible—the exact pressure it would require to drive it so many inches into the ground. No one is more ready than ourselves to estimate at its full value, the real permanent benefit the various engineering schools and colleges have conferred upon engineers, but a line must nevertheless be drawn somewhere. We should regret to witness a profession, which is essentially practical in its character and duties, reduced to a mere display of mathematical dexterity, book lore, and paper work.

NOTES ON TIMBER.

From "The Building News."

Many years ago it was comparatively easy to import trees from the north of Europe of sufficient size to make topmasts for the largest classes of men-of-war. Now, however, little timber of the required dimensions could be produced, even had we not now given the preference to iron masts. In fact, the mast trade is declining. Canadian yellow pine masts used formerly to be plentiful at 30 in. in diameter, but none, or nearly none, such are now to be met with; nor if we wanted wooden stern-posts for our men-of-war could we now procure them from the old sources of supply. These are only one or two instances which might be brought forward to show that if timber of large dimensions is wanted from the ports we have been so long in the habit of dealing with, it will not be readily forthcoming, except at a vastly enhanced cost, and perhaps even then it may be impossible to purchase it. For both oak and fir we have long been almost dependent on foreign or colonial supplies. Oak certainly still comes to our markets from our own native plantations, but the supply is limited, for as trees are felled, the remainder are more and more looked upon as ornamental trees, not destined for the axe. Although it is usual to speak of fir and pine as "fir timber," still there is a difference between the two—witness Riga fir and North American pine. Du Hamel says pines have the leaves thready and slender, growing in clusters from the same leaf-stalk, while firs have straight leaves, each growing separate, but many growing on the same leaf-stalk, like the teeth of a comb. These are the general characteristics between the two sorts of trees which produce fir timber. The pines grow with their trunks much less tapering towards their tops than the firs; they are therefore, from shape, more adapted for masts than firs. Their wood is also more resinous, and the resin is of a more glutinous nature, and therefore less easily evaporated; it also, in consequence of this quality, enables the timber to resist better the absorption of water or moisture when exposed to it. The pine is more durable than the fir, and its fracture is, even when partially decayed, much more fibrous, and takes place with more previous warning. Riga fir is not only extremely flexible and elastic, but it is by far the most durable of all pine timbers. The American continent produces red pine, which is often used instead of Riga timber, but so far as London is concerned, the imports have dwindled down to almost *nil*. The red pine thrives well in Scotland, where it is called Scotch fir, but the timber will not bear comparison with that imported, although it is

often included under the generic name of "Riga." Yellow pine, which is principally imported from Quebec, has neither the flexibility nor the elasticity of the red pine, nor is it so durable, but it is much lighter. For the inside work of houses, such as panels, sashes, etc., it is invaluable, and is eagerly bought up by builders for such purposes. It grows in Great Britain, but it does not thrive in this climate. Norwegian fir is largely imported, principally in the shape of battens and boards; but the wood is generally small, and the Swedish of the same description finds more favor from its larger scantling. Cedar would be among the most valuable of all timber trees were it sufficiently common to be available for building purposes. It is almost indestructible from time, and no insect will ever attack it. It requires a more generous soil than any other of the tribe of pines, and is a timber of very slow growth. Pitch pine is now well known, and has taken its place as a building and furniture wood.

The sap-wood of all fir timber is useless, and generally there is a large proportion of it in comparison with the quantity of heart-wood. But it is a curious fact that there appears to be a difference between the pines and the generality of hardwood timber in this: that a small proportion of sap-wood in fir is indicative of the inferiority of the timber. Thus, the red pine of Scotland has fewer layers of sap-wood than either the Baltic or Canadian red pine. As a general remark, it may be stated that the greater the quantity of sap-wood there is about a tree of any description of fir timber, the better will be the quality of the mature wood.

Larch is imported from Canada under the names of Hackmatack and Tamarack. which have every appearance of being identical with the Scotch larch. Cabinet-work of great beauty has been made from this wood; it polishes well, and when seasoned is not found to warp or shrink. In some of the public buildings of Venice there are said to be single-pieced beams of larch which are 120 ft. in length. It must be very durable, for it is almost the only wood which was used in the palaces and public buildings of that city.

Teak is now an important article of commerce. The importation from Moulmein dates since the Burmese war, and its value as a ship-building timber is highly appreciated; but inferior as the Pegu and Moulmein teak is in quality, when compared with the Bombay teak, it is infinitely preferable to the Saul or the Sissoo. All descriptions of teak, if sound, free from defects and sap-wood, are proof against the white ants—a matter of the greatest importance in India—whereas in this market it is valued for its hardness and durability. The teak grows to a great height, 70 to 80 ft., and more, but cannot be easily obtained of good quality of that size. Jarrol, Toon, and similar Indian woods, are not in use in Great Britain, and need not be described.

British Guiana Greenheart is another well-known timber. It is a hard, close-grained wood, having, like teak, an oily feel to the touch. Its specific gravity is about equal to that of the African oak, but it is decidedly superior to it in strength, toughness, and durability. These, however, are not its chief advantages. Its great value consists in its being completely exempt from the attacks of worms. It is exceedingly hard, and difficult to work as planking. There is another Guianian timber, the Siruaballi, of a softer texture, and much used for planking, as it is also said to be able to resist the ravages of the worm.

At whatever period timber is felled, it requires to be thoroughly seasoned before it is fit for the purposes of carpentry. This object of seasoning is partly to evaporate as much of the sap as possible, and thus to prevent its influence in causing decomposition, and partly to reduce the dimensions of the wood, so that it may be used without inconvenience from its further shrinking. Timber seasons best when placed in dry situations, where the air has a free circulation around it. (Evelyn, in his "Sylvia," has some advice on this head, as applicable now as when he wrote it.) Gradual drying is a better preservative than a sudden exposure to warmth, even of the sun; for warmth, abruptly applied, causes cracks and flaws, from the sudden and unequal expansion produced in different parts.

Two or three years' seasoning is requisite to produce lightness and durability in the woodwork of buildings. It must be observed that seasoning in the common way only removes a portion of the aqueous and volatile matter from the wood. The extractive, and other soluble portions still remain, and are liable to ferment, though in a less degree, whenever the wood reabsorbs the moisture.

Such, indeed, is the force of capillary attraction, that wood exposed to the atmosphere in our climate never gives up all its moisture. There are so many methods of preserving wood, each patentee having reason to think his own process the best, that it will be as well to refrain from investigating their respective claims to excellence. It is the opinion of some that woods abounding in resinous matter cannot be more durable than others, but the reverse of this is proved every year in the pine forests of America, where the "light wood," as it is called, consisting of the knots and other resinous parts of pine trees, remains entire, and is collected for the purpose of affording tar, long after the remaining wood of the three has decayed. In the salt mines of Poland and Hungary the galleries are supported by wooden pillars, which are found to last unimpaired for ages, in consequence of being impregnated with the salt, while pillars of brick and stone, used for the same purpose, crumble away in a short time by the decay of their mortar. Wooden piles, driven into the mud of salt flats and marshes, last for an unlimited time, and are used for the foundations of brick and stone edifices. The application of salt in very minute quantities is said rather to hasten than prevent the decay of animal and vegetable bodies. Yet the practice of docking timber, by immersing it for some time in sea water, after it has been seasoned, is generally admitted to promote its durability. There are some experiments which appear to show that, after the dry rot has commenced, immersion in salt water effectually checks its progress, and preserves the remainder of the timber. If care be taken to renew the coat of paint as often as it decays, wood on the outside of buildings, may be made to last for centuries, but painting is no preservative against the internal, or dry, rot; on the contrary, when the disease has begun, the effect of paint, by choking the pores of the wood, and preventing the exhalation of vapors and gases which are formed, tends rather to expedite than prevent the progress of decay. Indeed, sound, well-seasoned wood will last longer unpainted than painted, for it is impossible to thoroughly dry it, and a day in a newly-built house causes moisture to be absorbed. To show the difference between seasoned and unseasoned wood, it may be remarked that unseasoned English oak (from experiment) weighs 62 lbs. 8 oz. per cubic foot; seasoned from 13 to 20 years, it weighs 45 lbs. 9 oz. per cubic foot. French oak unseasoned, 68 lbs. 2 oz.; seasoned, 48 lbs. 0¼ oz. African oak, unseasoned, 64 lbs. 1 oz.; seasoned 13 to 20 years, 60 lbs. 3 oz. Teak, unseasoned, 48 lbs. 11 oz.; seasoned 19 years, 42 lbs. 2¼ oz. Dantzig fir, unseasoned, 39 lbs.; seasoned, 32 lbs. 9¾ oz. These statistics will explain why builders are so anxious to procure dry materials, and how it is that so much objection is made to sap-wood.

INDIA AND EASTERN TIMBER.

Cedar is a commercial term given to the woods of several distinct kinds of forest trees, the timbers of which are distinguished as red and white cedar, Barbadoes and Bermuda cedar, cedar of Lebanon, pencil cedar, bastard cedar, and some of those that grow in America, some in Europe, and some in Asia. The lofty Deodara, a native of the Himalayas, with fragrant and almost imperishable wood, and often called the Indian Cedar, is sometimes referred to the genus Pinus, and sometimes to those of Cedrus or Larix, with the specific name of "deodara." But Dr. Hooker is of opinion that the Deodar and the Cedar of Lebanon are identical. The woods of several of the Coniferæ are called cedars. But in India the term Bastard Cedar is applied to the *Guazuma tomentosa*, while in New South Wales the term White Cedar is applied to *Melia azerach*, and Red Cedar to that of *Flindersia Australis*, and the name is also given to the woods of the *Cedrela toona* and *Chickrassia tabularis*.

In China, a kind of cedar, probably a cypress, called Nan Mah, or Southern Wood, which resists time and insects, is considered particularly valuable, and is especially reserved for imperial use and buildings, and the cedar wood of Japan, according to Thunberg, is a species of cypress. The cedar of Guiana is the wood of *Icica altissima*. The whitewood or white cedar of Jamaica is *Bignonia leucoxylon*. The word "cedar," in the United States, is applied to various genera of the Pine family. The Virginian red cedar is a juniper; is called red, or pencil cedar; the white cedar of the Southern swamps is a cypress. Under the term cedar, Col. Frith describes a reddish colored wood of Palghat, specific gravity 0.507, as a large tree, wood aromatic, and used for furniture; and under the name of cedar root, a very

aromatic wood, used for ornamental furniture in Palghat.

Specimens of the wood of the Indian Cedar (*Cedrus deodara*) and of the cypress from the Himalayas, were shown by Dr. Royle at the Exhibition of 1851. The former has been introduced into England as a beautiful ornamental tree, and appears to promise well as a useful timber tree, as the wood works well and freely.

The Toona (*Cedrela toona*) is a large and valuable tree, which grows in varying abundance at the foot of the Himalayas, also in the north-eastern provinces, and to the south in Bengal, and in both peninsulas of India. It is rare in the central provinces. In the Punjaub it grows up to 2,500 ft. to 4,800 ft., with 7 ft. to 12 ft. in girth. Its growth there is rapid; its darkish wood is not subject to worm or warp, it looks well when properly polished, and is there a favorite for cabinet-work. Mr. R. Thompson says it grows to a large size in the outer, moist valleys of Kumaon and Ghurwal, and hill-men will not sell their trees. In Kumaon, trees with girths of 12 ft. to 16 ft. yield planks up to 3 ft. broad, but 2 ft. is the average. In Coimbatore, it is a valuable timber tree of large size, and its reddish colored wood is used for cabinet-making purposes. It is not a common tree in the Bombay forests, but is found in some of the greenwood jungles about the ghats, and also in the hill range abutting on the Rajpooree Creek to the south. The wood is a choice one for cabinet-makers' purposes, but it is not used for any others, except for house beams, when it is procurable in sufficient quantities. A tree is also found, Dr. Brandis tells us, on the hills and plains of British Burmah, plentiful in some districts, and if not identical with the toon of Bengal, certainly neerly related to it. A cubic foot of the Burmah wood weighs 28 lbs. In a full grown tree, on good soil, the average length of the trunk to the first branch is 40 ft., and the average girth, measured at 6 ft. from the ground, is 8 ft. It sells in Burmah at 8 annas per cubic foot

The lofty Deodara (*Cedrus deodara*) is a native of the Himalayas, and has an almost imperishable wood. Dr. Hooker is of opinion that it is identical with the Cedar of Lebanon, and this view is generally concurred in. It grows at 4,000 ft. to 10,000 ft. in many parts of the Himalayas, from the Ganges to beyond the Indus at Safed Koh, and the mountains north of Jellalabad. It is a very handsome tree, with a yellow-colored, easy-worked, straight-grained, and durable wood, and pillars of it, in the great mosque, are said to be of the year 804 Hejira, but those of the Hindoo temples there are said to be 600 or 800 years old. Insects do not attack it. It is strong and elastic, and not too heavy. It is used for knees of boats, and for all building purposes. A tree takes from 80 to 120 years to reach 6 ft. of girth, attains a height of 100 ft., 120 ft., even over 200 ft., and girths of from 25 ft. to 42. It is the best of all the coniferous timbers, and yields a valuable empyreumatic oil.

With reference to the central province forests, Major Pearson gives some very valuable information. At the present time the only forests in which teak of good size is procurable are, 1st, the forest of Boree, at the foot of the Puchmuree or Mahedeo hills, and those of Sowleeghurh and Jamgurh in Baitool. 2d. The forests around the Bormeyr River in Mundla. 3d. The forests of Lahora, Konkeir, and Panabarras, of which the latter is the centre, between Raepore and Chandah; and 4th, the forests of Aheree on the Godavery, between Seroncha and Chandah. The last two named belong to Zemindars, the first two only are Government property. There is also teak found of large size in the Gurjat States, 120 to 150 miles south-east of Raepore; but it is so remote that it can hardly be considered as belonging to the available resources of the country. It is believed, however, not to exist in any extraordinarily large quantity; indeed, Lieutenant Forsyth's report on the Kuvriar forests represents 12,000 trees in all. In Boree, including the Baitool forests (which latter, however, are practically worked out), there may be 10,000 available timber trees; in Mundla there are about half that quantity remaining. In the forest of which Parnabarras is the centre, there is still practically, a perpetual supply, if they are only worked with care, as a vast supply of trees are there found in every stage of growth. About Dorwa in Parnabarras alone he calculated there were 10, 000 trees available for felling, and 30,000 more from 2 to 2½ ft. in girth, all fine, promising young trees. From the distance of the forests, and excessive weight of the timber, Saul does not come into much use. There is, however, a fine forest

(a solitary patch) in the Daniwah Valley at the foot of the Puchmarree hills, which is now being worked, and the Executive Engineers at Jubbulpore and Saugor supply themselves with this timber from the Rewah State, 50 or 60 miles east of Jubbulpore, and from the Government forests in Beejoragogurh. Of all other timbers, good, bad, and indifferent, and many of them bad, the demand for sleepers for both branches of the Great Indian Peninsula Railway, east of Bosawul, has almost cleared the forest within 50 miles of the railway lines of every tree that would yield a sleeper; nor has the supply of them done much good, as a very few years will have to elapse before all have to be replaced. This is being done partly by Saul, in a very small degree by Teak, but chiefly by iron-girt sleepers.

Western Mysore produces valuable timber trees, useful for building and cabinet-making, such as Boghy, for furniture, strong and tough; Soojhal, useful for all purposes, in color a light brown, long grain, and rather open; Hoonsay, with red and black streaked heartwood, close-grained and knotty, which makes excellent naves of wheels, oil-mills, mallets, etc., and is valuable for brick and tile burning; Biti, an open-grained timber, something like rosewood, which makes up into good furniture of all descriptions; Honagul, a building timber, also used for furniture; Wulla Honay, a light-colored, open-grained timber, a very excellent description of wood suitable for house-building and furniture; Nundee, of which substantial bridges are built; Nellee, of a dark flesh color, smooth, very close grain, compact and tough, making fine veneers, does not decay under water, and is well adapted for turning; Novoladdi, a greenish-brown, dull, close-grained timber, which polishes well, and is much liked by builders and others; and Handiga, useful for furniture and for the turner, etc.

These are but a few of the forest products of India, but will serve to show the vast and, comparatively speaking, still undeveloped timber resources of that country, which cannot be otherwise than a matter of great interest to all builders in Great Britain.

SYMPATHETIC VIBRATIONS IN MACHINERY.

By JOSEPH LOVERING.

From "Iron."

The vibrations I propose to demonstrate are those which are pitched so low as not to come within the limits of human ears, but which are felt rather than heard. I wish to show how these may be seen as well as felt.

All structures, large or small, simple or complex, have a definite rate of vibration, depending on their materials, size, and shape, and as fixed as the fundamental note of a musical chord. They may also vibrate in parts, as the chord does, and thus be capable of various increasing rates of vibration, which constitute their harmonics. If one body vibrates, all others in the neighborhood will respond, if the rate of vibration in the first agrees with their own principal or secondary rates of vibration, even when no more substantial bond than the air units this body with its neighbors. In this way mechanical disturbances, harmless in their origin, assume a troublesome and perhaps a dangerous character, when they enter bodies which are only too ready to move at the required rate, sometimes even beyond the sphere of their stability.

At one time considerable annoyance was experienced in a cotton mill because the walls and floors of the building were so violently shaken by the machinery; so much so that on certain days a pail of water would be nearly emptied of its contents, while, on other days, all was quiet. Upon investigation it appeared that the building shook in response to the motion of the machinery only when it moved at a particular rate, coinciding with one of the harmonics of the structure; and the simple remedy was to make the machinery move at a little greater or a little less speed, so as to put it out of tune with the building.

We can easily believe that in many cases these violent vibrations will loosen the cement and derange the parts of a build-

ing, so that it may afterwards fall under the pressure of a weight which otherwise it was fully able to bear, and at a time, possibly, when the machinery is not in motion. Large trees are uprooted in gales of wind, because the wind comes in gusts, and if these gusts happen to be timed in accordance with the natural swing of the tree, the effect is irresistible. The slow vibrations which proceed from the largest pipes of a great organ, and which are almost without the range of musical sounds, are able to shake the walls and floors of a building so as to be felt, if not heard.

We have here, also, the reason of the rule observed by regiments on the march, when they cross a bridge, viz., to stop the band, and to break step. This is lest the measured cadence of a condensed mass of men should urge the bridge to vibrate beyond its cohesive force. A neglect of this rule has frequently led to accidents. The Broughton Bridge, Manchester, gave way beneath the measured tread of sixty men only, who were marching across it.

Robert Stephenson has remarked ("Edin. Phil. Journal," vol. v., p. 255) that there is not so much danger to a bridge when it is crowded with men or cattle, or if cavalry are passing over it, as when men go over it in marching order.

A chain bridge crosses the river Dordogne on the road to Bourdeaux. One of the Stephensons passed over it in 1845, and was so much struck with its defects, although it had been but recently erected, that he reported them to the authorities. A few years afterwards it gave way when troops were marching over it.

A few years ago a similar disaster befell a battalion of French infantry while crossing the suspension bridge at Angiers. Reiterated warnings were given to the troops to break into sections, but the rain falling heavily, the orders were disregarded, the bridge fell, and 280 men were killed.

When Galileo set a pendulum in strong vibration by blowing on it whenever it was moving away from his mouth, he gave a good illustration of the way in which small but regularly repeated disturbances grow into consequence. Professor Tyndall tells us that the Swiss muleteers tie up the bells of their mules, lest the tinkle should start an avalanche. The breaking of a drinking glass by the human voice, when its fundamental note is sounded, is a feat instanced by Chladin, who mentions it as an experiment frequently repeated by an inkeeper for the entertainment of his guests, much to his own profit.

The bark of a dog is able to call forth the response from certain strings of the piano; and a curious passage has been pointed out in the "Talmud," which discusses the indemnity to be paid when a vessel is broken by the voice of a domestic animal. If we enter the domain of music, there is no end to the illustrations which might be given of these sympathetic vibrations.

In the case of vibrations which are simply mechanical, without being audible, at any rate in a musical sense, the following ocular demonstration may be given:—A train of wheels, set in motion by a strong spring wound up in a drum, causes a horizontal spindle to revolve with great velocity. Two pieces of apparatus like this are placed about 10 or 12 ft. apart. On the ends of the spindles, which face each other, are buttons about an in. in diameter. The two ends of a piece of white tape are fastened to the rims of these buttons. When the spindles, with the attached buttons, revolve, the two ends of the tape revolve, and in such directions as to prevent the tape from twisting, unless the velocities are very different. Even if the two trains of wheels move with unequal velocities, when independent of each other, their motions tend to uniformity when the two spindles are connected by the tape. Now, by moving slightly the apparatus at one end of the room, the tape may be tightened or loosened. If the tape is tightened, its rate of vibration is increased, and, at the same time, the velocity of the spindles is diminished on account of the greater resistance. If this tape is slackened, its rate of vibration is less, and the velocity of the spindles is greater. By this change we can readily bring the fundamental vibration of the tape into unison with the machinery, and then the tape responds by a vibration of great amplitude, visible to all beholders. If we begin gradually to loosen the tape, it soon ceases to respond, on account of the two-fold effect already described, until the time comes when the velocity of the machinery accords with the first harmonic of the tape, when the latter divides beautifully into two vibrating segments, with a node at the middle as the tension slowly diminishes, the different harmonics are successively developed, until at length the tape is broken up into a number of segments only an inch

or two in length, presenting the appearance of a beautiful wave line :—

The eye is as much delighted by this visible music as the ear could be if the vibrations were audible. A tape is preferred to a cord in this experiment, because it is better seen, and any accidental twist it may acquire is less troublesome.

THE NARROW GAUGE DISCUSSION.

From "Engineering."

The Session 1872–73 of the Institution of Civil Engineers will long be a memorable one, on account of the discussion arising out of Mr. W. Thomas Thornton's paper on the relative advantage of the 5 ft. 6 in. gauge and of the metre gauge for the new State railways of India. This discussion, if we may give that title to what was little more than a systematic attack upon narrow-gauge railway principles, extended to wider limits than probably any other in the archives of the Institution, and may, as was doubtless intended, exercise an important influence upon the immediate future of railway construction in India.

In fact the influence which has been brought to bear upon the subject has already made itself felt, in the recent order which has been issued, to arrest the progress of narrow-gauge lines in India, until the question of gauge has been again considered.

It would be out of place for us to review the action which has been taken in this matter by prejudiced and interested engineers. We should have to revert to a period immediately succeeding the death of Lord Mayo, when the chances appeared possible of reversing the joint decision arrived at by him and by the Duke of Argyll, and of maintaining the broad gauge for the contemplated Indian extensions. We should have to trace out the various means by which, through a long period, pressure was gradually and steadily brought to bear upon the Indian Government, until, influenced by the constant assurance that a grave mistake had been committed, the metre gauge was put upon its trial at the bar of the Institution with Mr. Thornton for its advocate; when this arrived the end so long aimed at was reached, and little justice could be expected from those who were most eager to be examined as witnesses for the prosecution, and who at the same time constituted themselves as judges. After the discussion terminated, it was decided to step aside of the usual practice at the Institution, and publish a verbatim report of all that had been said at the various meetings upon the subject, without delay, in order that no time may be lost in bringing the influence of the Institution to bear in reversing the obnoxious decision of Lord Mayo. We need not trouble to inquire here whether, in its eagerness to achieve a desired purpose, the Council of the Institution has not outstepped its functions, and for the present we may deal only with the general tone and arguments of the memorable discussion, deferring till a more convenient opportunity, a more detailed criticism.

The ground occupied by Mr. Thornton is briefly as follows: That by adopting the reduced gauge for the contemplated 10,000 miles of new line, the Indian Government would effect an approximate saving of £10,000,000, and would provide railways which should be fully equal in capacity to those already existing.

The saving claimed was shown to be within reasonable limits, both from actual experience in the construction of narrow-gauge railways, and from careful estimates made by our most responsible engineers; while as to the capacity of a narrow-gauge railway, experience is again teaching us every day, that a railway of a metre, or 3 ft. 6 in. gauge, can with ease convey as much traffic as the 5 ft. 6 in. Indian railways, and that with proper working they can carry more.

Mr. Thornton showed clearly that the inconvenience of a break of gauge had been grossly exaggerated, and the cost of transferring goods would form in India, but a very insignificant proportion of the saving effected in construction. He omitted to add that the greater economy in working, which is possible upon narrow-gauge railways, would far more than compensate for the cost of the exchange stations.

In assailing the facts advanced by Mr.

Thornton, several Tuesday evenings were expended, and numerous speakers exhausted all their arguments upon the subject, without, however, damaging the position Mr. Thornton had taken up, and in his closing remarks that gentleman showed himself fully equal to reply to the objections which had been raised.

A brief review of the reply may perhaps convey the best idea of the salient points in the discussion, and the tone of those who took a part in it. Mr. Thornton very happily compared the speeches of Mr. Andrew and Mr. G. P. Bedder to that of the barrister who, having no case to defend, abused the plaintiff's attorney. Not that there was much fault to find with Mr. Andrew in this respect, he did not step beyond the limits of special pleading. But it was very different with Mr. Bidder, and the excuse which Mr. Thornton made for that gentleman, "that it was only a way he had," was quite an insufficient one. Amongst other things, Mr. Bidder stated that "a packed Commission, with a Duke for a dry nurse," was sent to Norway to inspect the narrow-gauge system of that country. This has only one signification. A packed Commission is a Commission brought "together unfairly and fraudulently for the attainment of some unjust end." Therefore Mr. Bidder gave to the world the statement that the Duke of Sutherland, Mr. John Fowler, Major-General Strachey, Mr. Rendel, and others, had been in fraudulent collusion to bring about an unjust end, and therefore that Mr. Fowler on the one side, and General Strachey and Mr. Rendel on the other, had submitted reports to the Indian Government which they knew were dishonest. This being the most striking remark in Mr. Bidder's speech, we need not consider it further.

Carefully comparing the different estimates of economy in first cost that could be effected by the adoption of the metre gauge, Mr. Thornton showed clearly that the sum he had stated, namely, of £1,000 a mile, was within the mark. With reference to the objections raised at the meeting against the evils of a break of gauge, which one gentleman contended would be infinite, and another asserted could not have a money value assigned to them, Mr. Thornton contented himself by pointing out that on a branch of the East Indian Railway, the actual cost of transferring goods is only 3d. a ton; whilst at another place upon the Eastern Bengal, the cost of shifting freight between the railway and boats is but a trifle over 5d. a ton. These prices, which correspond with those in all other parts of the world for this work of transfer, should surely be sufficient to answer all the foolish objections raised upon this point. Estimating, then, the total cost of shifting the freight that would be carried upon the proposed 10,000 miles of narrow-gauge railway, Mr. Thornton assumed that the excessive quantity of 3,330,000 tons a year would have to be transferred. This at a cost of 4d. per ton would involve an annual outlay of £50,000, which would have to be deducted from the saving effected in first cost, and which, taking the interest at 5 per cent., would represent a yearly income of £500,000. By what process of reasoning, asked Mr. Thornton, could it be proved that the Indian Government would be justified in incurring an expense of £500,000 a year in order to save £50,000?

One reason, and that a powerful one, could be advanced against the adoption of the narrower gauge. If it could be shown that the carrying capacity of the rolling stock is unsuited to military requirements, the extra accommodation would become necessary, irrespective of cost. But here again experience is at hand, and the rolling stock designed and built by Mr. Rendel for the narrow-gauge Indian lines shows what can be done in this matter; while, as Mr. Charles Douglas Fox had stated, rolling stock of precisely the same width as that upon the Indian 5 ft. 6 in. railways, had been long in use upon the Canadian 3 ft. 6 in. lines. Again, Mr. Allan contributed some valuable narrow-gauge railway experience from the United States, gathered from the Denver and Rio Grande 3 ft. line, which entirely answered the absurd statement of Captain Galton; that metre gauge ambulance cars could only convey two men. The latest type of the German ambulance car, as exhibited at the Vienna Exhibition, accommodates ten men, allowing to each 138 cubic feet of space. The Denver and Rio Grande wagons are built of such a size that they would accommodate six men with the same allowance to each.

With regard to the carrying capacity of the metre gauge in times of emergency, it must be remembered that there is only one mode by which the full measure of usefulness of such railways can be developed; that is, by the aid of Fairlie engines. Mr.

Lee Smith, in the course of the discussion, contended that the quantity of rolling stock proposed by the Government of India, especially for the Punjab lines, was entirely insufficient, and, therefore that the estimate of cost was incorrect. Upon this point we cannot do better than quote part of Mr. Thornton's reply; we regret that want of space will not allow us to give it *in extenso*.

Mr. Lee Smith's proofs were given thus: Twelve trains a day, of 30 metre-gauge vehicles each, or 360 vehicles together, would, he said, be required for the transport of 1,000 fully equipped men per day, or for 7,000 men per week; 11,000 men would therefore require 560 vehicles. Now the whole length of rail from Peshawur to Kurrachee being, in round numbers, 1,100 miles, its aggregate rolling stock, at the rate assumed by Mr. Thornton, and understood to be proposed by Government—namely, 1 engine and 30 vehicles per 13 miles—would be 84 engines and 2,538 vehicles, which latter figure, divided by 30 vehicles—Mr. Lee Smith's allowance of vehicles for one train—would yield a quotient of what? According to Cocker, of about 84 trains; according to Mr. Lee Smith, of only 2. What was to be thought of such arithmetic? What but that a man might be a responsible engineer, and yet be no geat adept at ciphering?

We regret that our space this week will not permit of our following this subject further at present, and indeed a review of the whole discussion would extend beyond the limits of many articles.

We should, however, allude to the concluding remarks of the President, who delivered an opinion decidedly adverse to narrow gauges. Moreover, the amount saved was, according to him, insignificant. What is £10,000,000 for India, with her population of 200,000,000?—only a shilling per head, or one-twentieth of a shilling for interest upon the whole amount!

On the other hand, it might be suggested that the saving of the extra £10,000,000 might mean half a million less profit to the engineers who carried out the works. But such a consideration is, of course, one entirely without weight.

THE ENERGY OF GRAVITY, WITH ESPECIAL REFERENCE TO THE MEASUREMENT OF IT.*

From "Journal of the Society of Arts."

The energy of gravity is one of the most silent and all-pervading of the energies of the imponderables. Although we may not be conscious of the fact, there need be no doubt that, were this energy to cease, we should be like those whom Milton describes as

> "Upwhirled aloft
> And sent transverse, ten thousand leagues awry,
> Into the devious air."

This calamity is averted by gravity putting forth that energy allotted to it by the Creator, and the work thus done enables us now to sit at ease, and gives us houses in which to dwell.

If, then, it be asked, where do we find this energy? we may say, "Look around." In this room, gravity, inasmuch as we are at rest, produces but a static action; there is, however, a clock ticking, and there gravity is producing motion. The combined harmonious operations of the energies of gravity and vitality brought us together this evening. Thus it has been ever since the creation of man; and yet there is good reason for the surmise that the energy of gravity, even if known, was little regarded in the earlier ages of the world. A history of observations on the energy of gravity, or even of traces of the recognition of this energy in these ages, has yet to be written. Whether, by some of the early Greek writers, gravity was supposed to be a power innate, as a living principle—a spirit in every particle of matter; or whether this power had a residence at the centre of the earth; or whether it resided in an atmosphere surrounding each particle of matter; or whether Seneca, who lived about 38 A. D., was moved by a consideration of (to him) that mysterious principle we call gravity, to notice that the tides and the moon were somehow related, need not, this evening, concern us.

From the time of Seneca we may pass over more than 1,500 years, to the days of Galileo (A. D. 1600), who was perhaps the

* By Rev. ARTHUR RIGG, M. A.; a lecture of the Cantor course.

first person to notice that bodies in falling moved faster and faster. He attributed this to the effects of gravity, and considered that if he could retard speed whilst still permitting gravity to act, he might determine the law of increasing spaces in equal successive times. This he did by permitting a ball to roll down an inclined plane; friction on the plane caused the retardation, whilst gravity alone caused the motion. Thus he obtained the ratio of spaces in reference to succeding times; but he made no attempt to measure the absolute spaces when a body fell freely.

Next to Galileo in order of time must be placed Kepler, a German astronomer, who, about 1615, in his search after certain astronomical relations, existing apparently through the mutual attraction of the planets each on the other, was led to surmises respecting the universality of the mutual influences of material bodies.

The succeeding 50 years present a blank in reference to inquiries or investigations respecting gravity. Then came Robert Hooke, who was at the same time a mathematician, an astronomer, and a mechanician. He was Secretary to the Royal Society of England, and from 1666 to 1674, seems to have frequently turned an inquiring mind to the nature of that influence which he thought he could observe to be exercised by the sun and earth upon others of the planetary system.

The great and now (1873) universally recognized law upon this subject was first laid down by observations and reasonings of Sir Isaac Newton, which even at this day are regarded with an almost religious veneration by the advanced and intelligent men of every nation. Although it is said that Newton began in 1670 to form more clear conceptions of the law of gravitation than had been propounded by any of his predecessors, we must remember on what surmises he had to build.

Kepler, about 1615, and Robert Hooke, about 1666, had led Newton, so early as the above-named date (1670), to form these conceptions, and it is probable that he was confirmed and directed in his anticipation by the fact that Richer noticed, in 1672, that a pendulum conveyed from Paris (lat. 48 deg. 50 min. N., long. 2 deg. 20 min. E.) to Cayenne, in South America (lat. 4 deg. 56 min. N., long. 52 deg. 20 min. W.), did not vibrate in the same time. This recorded fact was as a demonstration to the mind of Newton of the deviation of the figure of the earth from perfect sphericity, and its oblateness, or compression at the poles. It was not, however, until the publication of his "Principia," in 1687, that the law of gravitation was fully established and enunciated.

Briefly expressed, the law, as anticipated by others and propounded by Newton, is this—that the attraction of one planet upon another depends upon the masses (not upon the "weights") and distances of the two planets; not, however, is the law of increase or decrease such, that at one half of a distance or double of any distance is the intensity of the attractive force doubled or halved. This might be a first impression. Astronomical facts refused to conform themselves to such a law. They rebelled. The parliament of planets had prescribed another code for the inter-relationships of their mutual attractiveness, and although it might perhaps have been readily inferred that, as the distance between the attracting bodies was increased, the intensity of attraction would be decreased, yet the law of that decrease was the one which Sir Isaac Newton announced. It is this—that if there be two heavenly bodies, say, the earth and the moon, and that these at a known distance are mutually exerting a certain attraction or drawing each to the other, then, if the distance be doubled, the influence will only be one-fourth of what it was. If the distance be trebled, then this influence will become one-ninth of what it was; if quadrupled, then one-sixteenth of what it was. Expressed in precise phraseology, the law of gravitation is that of the inverse square of the distances. Thus far satisfied the requirements of astronomers.

It is remarkable how much of the utilized information men possess has been derived from the observations of astronomers. The mechanism of the universe was known before Harvey discovered the circulation of the blood, or Watt constructed a steam engine. The astronomers seem to have been the pioneers of every branch of human knowledge. The Old and the New Testaments open astronomically. "In the beginning God created the heavens and earth." (Gen. i. 1.) "The wise men from the east came to Jerusalem, saying, where is He that is born King of the Jews? for we have seen His star in the east." (Matt. ii. 2.)

It must be remembered that the science

of astronomy in one important respect differs from all other sciences. Astronomers are observers only—they ascertain causes by watching effects. They cannot interfere with or alter the causes in operation. They cannot make experiments. That man presumed too much upon the powers of his astronomical friend, who having invited him to bring some of his acquaintance to see an eclipse of the moon by the aid of a telescope, and arriving too late, assured those who accompanied him that the astronomer was not only a personal friend, but also a very kind-hearted man, and he did not doubt that the eclipse would be done again in order that they might see it. Yet upon these observers all experimenters erect their fabrics. The gigantic and uncontrollable phenomena, and all the laws of the universe of planets —of the ebb and flow of the tides, of meteorology, of terrestrial magnetism and its connection with the sun, are the results of observation. They could never have been known by experiment; indeed, we could not so interfere with them as to make an experiment. Remember, experiment is an interference on our part, and a redirecting of energy into a new channel, in order that that may be observed which cannot otherwise be observed. Hence, if we wish to utilize observation it must be by the adaptation of an experiment in the presence of an observation—to contrive, in fact a system of apparatus which may enable us to take observations and at the same time to so control the elements of an experiment as to bring them within the range of our means of observation.

Such combination of experiment and observation is to occupy much of our attention this evening, as on the records of these men—Cavendish, Atwood, Kater, Sabine, and Baily, especially Captain Henry Kater, is built our system of measures and weights; for to them we are indebted for what must constitute a court of final appeal, should the time ever come when our present standards being totally lost, it is essential to re-establish them.

The energy of gravity is peculiar, and differs from those other energies with which we are to be concerned, in that it seems inexhaustible—its power is not proportioned to the work it does. All other energies are in process of exhaustion by work when that work is measured by motion; not so gravity. Imagine a large ball, and a second small one, which gravitates towards it—the number of these small balls may be increased, and still the influence of gravity on each ball is as intense as though there was only one small ball; no exhaustion from work done affects the energy of gravity, and yet it seems not to have any power of recouping its expended energies. There is no elasticity about it—at least, none in the hands of men.

For example, we can, in food, avail ourselves of affinity, and so, through the agency of assimilation, revive the energies of an exhausting vitality. Electricity can, upon a system of relays, or upon its extraordinary property of induction, renew at a distance, not only its pristine vigor, but an energy many fold greater than its original one. Light can have its intensity and purity restored by heat. Gravity remains in its solitariness. True, we believe that vitality, affinity, electricity, light and heat are independent of, and beyond the influence of, gravity; yet, we know them not—we cannot bring them within the ken of our senses, except when they are associated with what owns the dull, dead, inert, and yet powerful influence of the energy of gravity. For all means yet employed have failed to develop or detect the presence of these imponderables in a perfect vacuum.

This fact seems to give support to the suggestion that the "potential energy of gravitation may be, in reality, the ultimate created antecedent of all motion, heat, and light at present existing in the universe."

The mode in which we estimate or measure gravity is peculiar. It is the only one of those energies with which this course of Cantor lectures has to deal that tells its story upon a scale beam or spring balance. No concentrated rays of a tropical sun have ever caused an appreciable deviation of the most delicate balance; neither light nor heat imparted to a body *in vacuo* has ever required the friction of a gramme to be added to the other scale-pan. But when gravity is concerned we cannot add the most minute microscopical molecule without having the equilibrium disturbed.

Gravity alone, of all the imponderables, rises up equal to the burden laid upon it. Its power seems to increase with the amount of matter involved or work to be done. The more required from it, the more it does. You cannot overburden it.

An avalanche of rocks or a gossamer thread are equally the playthings of gravity.

For the purpose of these Cantor lectures, the law of gravitation which binds the planets in their courses is of little concern, unless we find that the same law binds the material elements with which we are concerned. The question whether the influence whose law Sir Isaac Newton so clearly propounded resulted from an unknown and ungovernable something, resident and centralized, as it were, within the planets, or whether it was a property of every molecule or group of molecules, was not set at rest until Nevil Maskelyne, the Astronomer-Royal at Greenwich, went to Mount Schiehallien, in Perthshire, in 1774, to calculate the density of the earth.

The mountain of Schiehallien has very steep sides. Mr. Maskelyne suspended plumb-lines from two opposite and nearly vertical sides. Now, if those plumb-lines deviated from what one may call vertically, they would have been caused to deviate by the attraction of the mass of the mountain. Thus Maskelyne examined this,—he had an instrument by means of which he could, by observations upon the stars, determine the exact direction that the plumb-line should take, and he found that the strings did not take that direction. Having done that on one vertical side of the mountain, he repeated the experiment on the other side, and found that the deviation there was opposite to that which it was on the first side.* Having determined that these strings no longer followed the vertical, he formed an estimate of how much this mountain attracted the plumb-bob at the end of the string, and so arrived at a conclusion that each particle of matter does attract every other particle. This was the first approximation to an estimate of that which forms a very important element in connection with other experiments. We may here state that in certain regulator clocks the makers put the single weight in the corner of the case, so that being removed to the greatest distance its influence upon the pendulum-bob, similar to that of Schiehallien upon the plumb-bob, may be the least possible.

This, then, established the fact that the power whose law Newton discovered was no gnome resident in some mysterious terrestrial centre, but was a property of every molecule of matter, and could not by any means or contrivance be separated from those molecules. Whether this property be within the molecule, or only in what may be called the atmosphere around the molecule, may be left to those who arrange theories.

Mr. Michael suggested to Cavendish an experiment which has ever since gone by the name of Cavendish's experiment, and from which was deduced the first pretty accurate calculation or actual measurement of the density of the earth. Cavendish, as you know, was a very wise man. It is said of him that "he was the richest wise man, and the wisest rich man, that the world ever saw." He left more than a million of money. He had also another quality which would be very desirable to cultivate in certain parts of this kingdom at the present time—he uttered fewer words than any other man who attained the same age is supposed to have done. He discovered many things, and, amongst others, he was the first to make an attempt at weighing the whole earth, and he weighed it with an accuracy which has only been confirmed in recent times.

The apparatus that Cavendish used was double the size of this which you see before you, but it was similar in construction. He had two balls of lead, similar to these large ones, suspended from a very light bar, that bar being trussed, as it is called, by a kind of triangle of wires, and the whole being attached to a hook in a pulley, round which he passed a cord, by means of which the balls of lead can be moved to any position you please. In order to exclude every external influence, the apparatus was inclosed in a room of its own, and to observe the phenomena that took place within that closed room lamps were applied at small orifices, and telescopes were placed at others. In addition to this apparatus with the two balls of lead which weighed about 3 cwt. each (as far as my memory serves), he had another apparatus placed below the other, as you see here. From a centre immediately under the pulley to which a frame carrying the leaden balls is attached, was suspended by an exceedingly fine wire a light rod with two little balls, less than bullets, and these balls held a certain position, and could not move from it beyond certain limits. Being placed in the afore-

* The deviation was noted by a zenith-sector, and after making the requisite corrections there was left an attraction which caused the two lines to be drawn together, so including an angle of 12 seconds due to the mountain.

said enclosed room, where there were no draughts or variations of temperature, or anything external to affect them, and they had been left for some time—say, for 24 hours, they became stationary, and would not move unless some external force were applied to them. At the end of the light bar carrying these small balls was an ivory scale and a pointer, and upon this was directed the light of a lamp from outside the room, whilst a knob was also placed outside, by turning which the motion of the large leaden balls could be controlled. At another orifice was placed a telescope, by means of which the motion of the pointer could be observed. After the little balls had become quite stationary, by the cord he very gently swung the larger balls to a position close to the small ones, and after a certain lapse of time, varying from a quarter of an hour to an hour, he observed the space through which the small balls were moved from the position they had occupied. It may be well to state that a thorough examination had been previously made as to whether any influence could be due to magnetism.

This experiment had to be repeated very frequently, because of the minuteness of the range of these balls and the magnification of it. The application of the results was to be so important. He therefore made three experiments on each occasion, and observed the position that the balls took. He also observed another matter which is of great consequence, although this evening to be passed over very lightly, namely, the number of oscillations made by the small balls before they came to rest. These balls oscillate like a pendulum, and by the number of times they swing before coming to rest certain calculations of great importance to the inquiry may be made. These calculations being completed, the conclusion he arrived at was that the earth was 5.4 (say 5½ times) heavier than water.

Now it is only right that you should be told how from these balls the density of the earth can be deduced. The mass or quantity of matter in these balls is known; their attraction upon the little balls is known from observation. The mass therefore of any other ball being known, we can tell the attraction that it would have upon these balls. It is quite clear that if this large ball had double the mass, it would have double the attraction at the same distance; if treble the mass, treble the attraction, and so on. Again, if the mass of the little ball was known and the attraction of the great one known, and the mass of the great one known, then if the mass of another ball is known, we shall get the attraction of that other ball. It should also be attempted to make clear how from these two balls we can weigh the earth, and probably it will keep your interest alive in the matter if informed that, in 1835 (Cavendish's experiments being made at the close of the last century, about 1798), Mr. Baily, the founder of the Astronomical Society, repeated them. Mr. Baily had been a stockbroker in London; he retired from business, and purchased a house in Tavistock place, the one, I believe, in which Mr. Digby Wyatt now lives. He there made many experiments, and some most extraordinary calculations, and did a large amount of astronomical work. Amongst other things he undertook to weigh the earth, and he weighed it as Cavendish did, namely, by an apparatus constructed on the same principle as the one before you. He swathed the box or chamber in which the balls were, with flannel, and put a gilded cover over all. He also lined the inside with tin-foil and connected it by a copper wire with the earth. These precautions were intended to neutralize, as far as practicable, changes in atmospheric temperature and terrestrial electricity. How important he considered it, you may judge from this, that he made more than 2,500 experiments with balls of this character; he sat watching them for 1,200 hours, and that number of experiments extended over some years. The repetition was planned in 1835, commenced in 1837, and concluded in 1842. The result of these 1,200 hours of watching, exclusive of the calculations which followed, led to the conclusion that Cavendish was right within a fraction of 2-10ths., that is to say, Cavendish concluded that the density of the earth was 5.4 times that of water; Baily concluded that it might be 5.6 times that of water.

It may be permitted to repeat the reasoning in order if possible to make clearer the principle on which it proceeds. From the weights we know the masses of the large ball and of the small one. We know that the small balls in relation to the large ones were free from the influence of gravity; we also know by observation how much the one attracts the other. Double the ball, and you get double the attraction, and

so on. Now, we know the size of the earth, and by placing this little ball on a spring balance, we know how much the earth will attract it. Therefore, the weight of the little ball being known, and the size of the earth being known, there is nothing left except the attraction to find; and, as we have the attraction from the two balls, we can, by a simple arithmetical operation, determine that the earth is 5.6 heavier than water.

This seems the best opportunity to name that the present Astronomer Royal (Prof. Airy), investigated by very different means and on very different principles, this question of how much heavier than a globe of water the earth is. Qualifying the conclusions from his experiments, as himself suggests, consequent upon certain geological considerations, it may be asserted that Cavendish's result is very nearly correct.

Time passed by; Cavendish's experiment was made, as I told you, about 1798, and Baily repeated it about 1835. We must now go back, as a matter of history, to Cavendish's time, and the next step we arrive at in determining the energy of gravity was the experiment that was made by Atwood, who was born in 1746. He was a Fellow of Trinity College, Cambridge, and was the first to entertain the idea of devising some plan of measuring the force of gravity. Let me endeavor to make this matter clear. Cavendish determined the density of the earth, but he did nothing whatever as to determining the force of gravity. Force, as stated in the first lecture, can only be measured by motion. We can easily obtain motion from the action of gravity, but we must observe that motion in order to measure force, If a weight be let fall it falls far too quick ly to permit of an estimate of the rate at which it falls. That rate is due to gravity. Atwood thought, as Galileo had previously done, that by causing the fall to be delayed, he might be able to draw a conclusion as to the exact force of gravity, and the plan he adopted was this. You are aware that the intervals between the ticks of a pendulum vary according to its length. Here is a pendulum, and you see the rate at which it is going; if, now, the pendulum weight be lowered, so as to lengthen the rod, you may observe that the pendulum ticks more slowly—in fact, it is now beating seconds. You were told, in the first lecture, that we must have a certain unit of measurement, and the *second* is the unit of measurement usually taken for time. If we want smaller measurements, for it is easy to divide the second into a hundred parts, they are taken by another contrivance. A very simple and sufficient one is a clepsydra, or water clock, arranged specially for this purpose.

What Atwood thought of doing in order to measure the force of gravity, having, you remember, no previous measurements to guide him (for Galileo did not touch the problem that Atwood proposed to solve), was to take two weights evenly balanced over pulleys such as these, the apparatus being most delicately made. You see that these two small weights are exactly balanced, one being at each end of a cord which passes over pulleys at the top of the apparatus, so that the weight in descending passes down in front of a graduated scale. These weights, then, are exactly balanced. Here are three very small weights, fractional parts of the ones which are suspended. If one of these small weights falls by itself, it would fall so rapidly that its rate of falling could not be observed; but if, whilst it is falling, it is caused to bring this mass of matter with it, the rate of falling will be retarded, whilst the law of the rate remains the same, that is, the law which governs the rate of falling will be similar, although the mass moved is increased. If now there be placed upon one of these balanced weights two of these little fractional weights, there is a something that will cause the connected mass to move, and this platform at the bottom will be struck about four seconds after the motion commences. The usual plan is to let the motion be commenced by electricity, which at the same time sets the pendulum in motion. You can count the strokes of the pendulum from the commencement to the end of the motion. You can see this mass of matter has been moved through 18 spaces in four seconds. If the measure be altered, you will readily understand that these fractional weights would carry it through a different space in the same time; if other weights be put on, they would carry it through other spaces. The experiment as made before the apparatus was brought here shows that the force of gravity is such as to cause a body to fall through about 32 ft. in one second, the meaning being that if this small weight had not been required to bring the other weights along with it,

then it would have fallen from rest through 32 ft. in the first second. That was the first attempt of estimating by measurement the force of gravity.

But Atwood's apparatus, though exceedingly good as matter of illustration, falls very far short indeed of that which Captain Kater adopted; and all that we have, and all that we know, of the form of the earth, and the true kinetic measure of gravity, spring from Kater's experiments, and not from either Cavendish's, Baily's, or Atwood's. Kater felt that if, instead of weights falling as they have fallen in the experiments of Atwood, he could observe the effect of gravity upon the weight falling, without associating it with other weights, if it could be kept quite distinct, and if in any way he could cause gravity to repeat the operation slowly and deliberately without any interference whatever, we might get at the conclusion much more rapidly than Atwood could by his arrangement, because the friction of the wheels, the weight of the cord, and other incidental matters affect the problem. What Kater did was to design a pendulum of which this is a copy. It was from a pendulum like this that not only was the force of gravity determined in all parts of England, but also the form of the earth itself has been decided and estimated. Our standards of weights and measures all come from a pendulum like this. If, in fact, the standards were all lost, it would be from such a pendulum they must be restored. Let me anticipate the conclusion by stating that when the standards were lost in the burning of the houses of Parliament, they were restored by seeking for copies, because the great number of corrections and the great difficulty of counting this pendulum and freeing it from interfering causes, are very serious obstacles. Few are aware of the enormous difficulty there is in placing a pendulum so as to be free from external influences and counting the oscillations of it.

Whilst upon weights and measures, your attention may be directed to a small piece of wood here, which is a model of the standard one-pound weight of Great Britain. It is one which a committee of learned men obtained, and this in my hand is a copy. The real standard is made of platinum. It is a cylinder 1.35 in. high and 1.15 in. in diameter. Observe there is a groove turned in it and there is an ivory fork by which it is to be lifted—these standards are not to be touched. There are only five of them made, and if ever the 1-lb. weight is lost in England, it is to be recovered, not by repeating Kater's experiments, but by copying one or other of these five standards. The five are kept—one at the Exchequer Chambers, at Westminster, one at the Royal Mint, one with the Royal Society, one at the Royal Observatory, Greenwich, and one is immersed in the sill of the recess on the east side of the lower waiting hall of the New Palace at Westminster.

To return, then, to Kater's experiments. He had first to determine a pendulum which should vibrate seconds in the latitude of London. He did it in the house of Mr. Brown, in Portland place, which house has an astronomical bearing from Portland Chapel of 74 deg. 38 min. 50 sec. west from north, the distance being 283 ft., and therefore the house is about halfway up Portland place on the left-hand side. In that house the pendulum was first adjusted. Nothing seems easier than to deal with a simple vibrating ball on a string. It is not, however, so easy as it seems. It cannot be made to swing in the same plane as this one now appears to do. If left free to choose its plane of vibration, it is seldom contented. It will not have a dozen swings in the same plane; it must, therefore, some how or other, be made rigid, and so prevented from such vagaries. Here is a small vessel of lead, hanging by a bundle of untwisted fibres from a hook, and you might think nothing could be easier than to let it swing backwards and forwards on the same path; but it will not swing for two minutes on the same path; hence, pendulums are all compelled to act in restrained paths, and generally supported on knife edges. French clocks have two strings of silk to the pendulum. These are fastened to two hooks at the top, and the pendulum rod being hung from the junction of the two silken cords, it is constrained to describe a path in a plane at right angles to that in which are the silk threads.

To return to the leaden vessel. It is now filled with fine white sand, and at the bottom there is an opening out of which the sand can trickle whilst the vessel swings freely. The figure caused by the sand falling on a board beneath will show the path that the vibrating body describes. It shall now be let go in what appears to be a straight line. If you watch that path you will see it is a very curious one. The

sand at once indicates that the ends of the line are travelling round, also that the line itself is becoming wide in the middle. In fact, a straight line is seldom formed by the falling sand from such pendulums. Even if a circular path be commenced, you will find it cannot be retained. It reminds one very much of one of the secular astronomical changes, that is, our year of 365 days and a fraction results from this gradual advance of the perihelion path of the orbit of the earth; observe it tends first to a straight line, then through an ellipse to a circle, and then a return action commences, and it will repeat this process from the straight line opening out again, and so pass on through various phases, until it comes to rest. Hence a pendulum constructed of a simple form is of no value, and yet it is in its simple form we require it. It was needful to assume for the purpose of the calculation that we can make a pendulum do that which this swinging vessel of sand is not doing.

Captain Kater was the first to deal with the case of converting the compound pendulum into a simple one. A pendulum is said to be a simple one when it consists of a heavy particle at the end of a very light thread. Such is almost an imaginary pendulum. All pendulums that we see are compound ones. Now, by pursuing the plan adopted by Captain Kater, he was able to obtain from the compound pendulum what would be the length of an equivalent simple pendulum. His pendulum has two pairs of knife edges, a pair at the upper end, on which it swings, and a pair at the lower end. He placed one pair of these knife edges on a smooth, hard surface, so that the pendulum might vibrate without anything causing it to continue its vibrations except the force of gravity. Now, if you look to this diagram you will see the motions of a compond pendulum. If it were short it would move thus, and if it were longer it would move more slowly. The black dots in the diagram represent the lower ends of pendulums of different lengths. Assume that the black dots are the ends of separate pendulums, one behind the other, from the same support, they will then occupy those places after the same interval of time from rest; if, however, these pendulums are united, then the one is kept back by the action of the other; now they are really united in a compound pendulum. There s, however, some point or other at which, if all these masses were concentrated, the velocity at that point would be the velocity of the mass, therefore such a pendulum would vibrate in the same time, and it would be called a simple pendulum. Kater found that this collected point, which is called the centre of oscillation, and this at which the pendulum is suspended, are interchangeable; in fact, he found that if the pendulum was accurately adjusted by means of these movable weights, he could suspend it upon a pair of the knife-edges, and he could get a certain number of vibrations in a minute or a second. Then, if he turned it upside down, assuming the pendulum to be right, and caused it to swing as before, upon the other pair of knife edges, it would make the same number of vibrations. These two points he marked, and the distance between them is the length of an equivalent simple pendulum. With such a compound pendulum as now described, and of which the one before you is a copy, counting the number of vibrations it makes, you can always deduce the length of a simple pendulum that would make the same number of vibrations.

What Kater did, then, was this—he had a clock kept going, strictly to truth, that is, to true astronomical time. The clock was furnished with a gridiron pendulum of the construction shown in the diagram, and so carefully arranged as not to be altered in length in consequence of change of temperature. On the bob of the pendulum, in front, was a white speck, as on the pendulum bob of this clock. He placed the compound gravity pendulum, which has been described, in front of the clock, the clock pendulum beating 86,400 strokes per mean solar day. The rate of the clock was determined by astronomical observations, and therefore, on any part of the earth's surface, it would be possible to so arrange the solar pendulum that the clock should always record 86,400 beats in a mean solar day.

Now let us turn to this two-ended pendulum of Capt. Kater. It is of an invariable length, and acted upon directly by the force of gravity; there are no weights or clockwork in connection with it. When it is up on one side, it is the power of gravity that causes it to fall, and it is gravity which keeps it going. If, for example, a powerful magnet be placed under that pendulum, then it will come to rest sooner than it would otherwise do, because it is pulled

down with greater force. If, therefore, gravity changes in its pull on this pendulum, it will tell on the rate of its vibrations. The rate of vibration of the equivalent simple pendulum is known, because it has been calculated from this compound one; hence, if this compound pendulum be placed in front of the clock keeping astronomical time, and if the vibrations of the pendulum be counted whilst the vibrations of the clock pendulum are being recorded, it might be ascertained whether the force of gravity varied in different places.

The means by which Kater compared these vibrations are very simple. You see the white speck, previously referred to, on the bob of this gridiron pendulum. He took a telescope and placed it at some distance on a level with that white speck. Between the white speck and the telescope, and near to the gridiron pendulum, swung the gravity pendulum, which moved slower than the other, being made a little longer. Keeping his eye upon the telescope, and directed upon a narrow piece at the end of the gravity pendulum, which was the same width as the white circular speck upon the bob of the clock pendulum, he could tell when the two coincided. As one pendulum swung slower than the other, it was quite clear that a coincidence must take place, and he noted the time of the coincidence. That was the beginning of counting vibrations, and he then waited until they separated and until the coincidence again took place a second time, which gave the number of the vibrations in a given time as recorded by the clock. Experiments like these were repeated very frequently and carefully, until at length the average was obtained as to the number of vibrations that this gravity pendulum made, compared with the vibration that the one on this mean solar clock made. Within the tube of this telescope there are crossings of very fine wires—so fine as to be hardly visible to unaided vision; the threads of a spider's web were formerly used for this purpose. A spider is taken in the fingers, then, if shaken, he would run his web out to save himself, and this web was placed in the focus of the eye-piece, and the threads were so that the crossing of them was in the axial line of the telescope. It was by looking along that axial line that the time was observed when the coincidence of these two pendulum marks took place. The accuracy with which that was done is more easily to be imagined than realized.

Assuming that this has been accomplished, let us look for a moment to other elements which would disturb the result. In the first place, the pendulum vibrated in air; and you were told, in the first lecture, that a body weighed in air and weighed in any other medium is not balanced by the same weight. Hence the effect of the air upon the pendulum has to be considered. Then the pendulum is vibrating in a changing atmosphere, sometimes warm, sometimes cold, and a change of the temperature causes an expansion or contraction; hence the effect of that expansion was to be considered. And, simple as it seems, to estimate whether a pendulum is longer or shorter is really very difficult. Indeed, great was Captain Kater's perplexity about it.

He measured the length of his pendulum thus; he formed a box similar to the one on the table, and laid his pendulum in it, and applied a microscope over one of each pair of opposite knife-edges, placing behind them a piece of white paper, so that the edge might be seen. He then applied the microscope. Again he put beneath them a piece of black paper, and he found that the measurement with the white paper was never the same as the measurment with the black paper. After describing how with microscopes he attempted to measure between knife-edge and knife-edge, by placing them when white on a black ground, and when black on a white ground, he adds:—"In one case, the knife-edges seemed to start forward to each other." This difficulty is summed up thus:—"On the cause of this extraordinary fact I can hazard no conjecture, and it remains an interesting subject for future investigation."

We now know that this resulted from a phenomenon called "irradiation." Hence he was bound, even in looking through those microscopes, to strike an average of the apparent errors.

Another error that occurred, which he also found great difficulty in remedying, and indeed never did remedy, so that in fact the experiments he made are liable to some infinitesmal corrections still, was this:—If a pendulum vibrates, as this one was doing just now, the air clings to it, and is carried along with it, from what is called the "viscosity" of the air. That viscosity is such, that if you were to put a short piece of gold leaf projecting edgeways upon the face of the pendulum bob, you would find that the gold leaf moved

with the action of the pendulum, and was carried along with it, so that it turned neither to one side nor the other. If, however, the gold leaf projected beyond a certain distance, then you would find it bend with the air. Therefore the atmosphere in immediate contact with the bob was dragged along with the pendulum, and that particular element Captain Kater was not aware of. Government, some years ago, in order to set this question at rest, had large vacuum chambers erected, and pendulums set vibrating in them, to ascertain how great an error was caused by the viscosity of the air.

Captain Kater having determined the length of this pendulum in the latitude of London in 1818, it was thought of great consequence to ascertain how far the force of gravity varied in different latitudes.

A memorial was presented to the Government in 1818 in order to ascertain by means of a pendulum how gravity varied throughout the British Isles, and Kater was commissioned to take steps for the purpose. Government placed at his disposal certain members of the Royal Corps of Engineers, with whom he set out to the north of Scotland, and made experiments at various places. He went up to Unst, in the Shetland Isles, then he came down to Portsoy, then to Leith, then down to Clifton in Yorkshire, then to Ashbury, then to London, and then to the Isle of Wight, and in each of those places he made certain experiments based upon the principles now too briefly described. This lecture would extend far beyond the allotted time if it entered into details with reference to local arrangements and special calculations. It may suffice to refer to the table on the wall for particulars of the results. The following is a copy of the table:—

Name of place-	Latitude of Place.			Vibrations in a mean solar day.	Length of a pendulum to vibrate seconds.
	deg.	m.	sec.		
Unst.....	60	45	28 2	86,096.90	39.17146
Portsoy.....	57	40	58 65	86,086.05	39.16159
Leith Fort.....	55	58	40.8	86,079 40	39.15554
Clinton	53	27	43 12	86,068.90	39.14600
Ashbury Hill..	52	12	55.32	86,065.05	39 14250
London.....	51	31	8.4	86,061 52	39.13829
Shanklin, or) rather Dun-) more.....)	50	37	23.94	86,058.07	39.13614

From this table it will be seen that the length of a pendulum vibrating seconds in the places respectively entered is that given in the last column.

These lengths are sufficient to enable a mathematician to calculate the force by which the pendulum is caused to swing. Now, as the only force causing the swing is that of gravity, such a calculation determines the force of gravity at that place in relation to its power to produce motion. Hence is deduced those 39 in., which, in ordinary expression is thus broadly stated to be the length for pendulums vibrating seconds in the latitude of London. Captain Kater deduced that 39.13829 in. was the length of a pendulum vibrating seconds in Mr. Brown's house in London. This length requires to be reduced to sea-level. Now, the rooms of the Royal Society, at Somerset House, are 81 ft. above low-water, and by the aid of a mountain barometer, made by Ramsden, Kater found the room in Portland place to be 2 ft. below those of the Royal Society, and as the length of pendulum above the floor was 4 ft., the elevation of pendulum above sea-level is 83 ft.* Now gravity varies inversely as the square of the distance of the place from the centre of the earth, therefore the length of pendulum must be increased in this proportion; and taking the radius of the earth for the latitude of Portland place to be 3954.583 miles, we have 39.1386 in. for pendulum vibrating seconds at the level of the sea in the latitude of London.

The greatest difference between the mean and that of any of the sets of experiments is only .00028 of an inch, or $\frac{1}{139869}$ of length of pendulum. The length 39.1386, as thus determined, is that required to perform one vibration, in $\frac{1}{86400}$ of a mean solar day, under the circumstances described, and at the level of the sea.

Finding how much could be obtained from this, with regard to the British Isles, Government commissioned Captain Sabine to go to different places on the east coast of Africa, the Island of Ascension, Bahia, Trinidad, Jamaica, New York, Greenland, and Hammersfest in Norway, and repeat Captain Kater's experiments. These experiments are repeated, and then, by an arithmetical process, which need not be referred to in detail, it was very easy, hav-

*There is reason to conclude that these measurements require to be corrected.—A. R.

ing given the number of vibrations of this invariable pendulum (for the distance between these knife edges did not vary), performed in a solar day, to calculate the power that was pulling it; and from that calculated power could be obtained the mass of the earth beneath the place where it was being pulled, making, of course, all the allowances for corrections and other circumstances. That calculated power gives the 32 ft. which we are all acquainted with as the measurement of gravity. The meaning of which is, that gravity will generate in a 1 lb. weight, in 1 sec., a velocity 32 times greater than that which it is agreed shall be called the unit or absolute measure of force. Put conversely—the absolute unit of force is equal to the weight of $\frac{16 \text{ oz.}}{32.2} = \frac{1}{2}$ oz. nearly.

Capt. Foster afterwards repeated these experiments, and made others, and from them has been obtained the figure of the earth, and calculations of all kinds used in scientific investigations throughout the globe depend upon them. Captain Foster was unfortunately drowned in the river whilst observing some of his experiments, but Mr. Baily undertook to tabulate his results, and completed the calculations on the data which had been obtained by Captain Foster's observations. The calculations Mr. Baily made for this purpose occupy many closely-printed quarto pages of figures. The result was solely to ascertain the length of the pendulum, and so deduce the figure of the earth. Great beyond all ordinary estimate is the amount of care, patience, preseverance, and anxiety that attends experiments of this kind.

ON THE MOLECULAR CHANGES PRODUCED IN IRON BY VARIATIONS OF TEMPERATURE.

By Professor R. H. THURSTON.

From "Iron Age."

1. To determine with accuracy what are the molecular changes which are produced in iron by variations of temperature, and of other physical conditions, it should be first ascertained, by experiment and observation, what are the normal relations of the molecules, and, afterwards, by similar means, in what way and to what extent those relations may be naturally or artificially altered.

So much having been done, the investigation of the changes in the mechanical properties of iron, which result from these molecular changes, is a secondary research, and should naturally follow the preceding, as its sequel.

The almost insuperable difficulties which are encountered in attempting to deal with particles of seemingly infinitesimal dimensions, and with intermolecular spaces of immeasurably minute extent, have, as yet, prevented a satisfactory prosecution of the first part of the investigation by even the ablest physicist, and the second division of the subject still remains as a problem only partially solved, notwithstanding the fact that a considerable amount of experiment and discussion has thrown light upon it.

2. The following may be considered as a statement of the most generally accepted views of the molecular constitution of matter; views which are usually considered to most fully accord with observed phenomena.

(1.) All matter consists of indefinitely small parts, having dimensions and forms which are unchangeable by finite power, and which are endued with the properties of impenetrability and inertia.

(2.) These "atoms" are separated by spaces which are absolutely very small, but which are immensely great in comparison with the atoms themselves.

(3.) Several atoms, when united by chemical force, form a molecule, and aggregations of molecules, with intermolecular spaces, make up the masses of all matter.

(4.) Forces, both of attraction and repulsion, exist between atoms and molecules. These forces vary in intensity with changes of distance between molecules. The resultant of these sets of forces is sometimes attractive and sometimes repulsive, changing at times, and under definite conditions, from the one direction to the other. There may thus be exhibited several alternations of attraction and repulsion within a very minute range.

(5.) At sensible and measurable distances

the attractive force varies inversely as the square of the distance between the centres of attraction, and is termed gravitation.

(6.) Gases manifest repulsion only in a degree which, in "permanent" or perfect gases, varies inversely as the volume of the mass.

Liquids exhibit a perfect equilibrium of attractive and repulsive forces, but offer immense resistance to the disturbance of that equilibrium, by effort to reduce their volume appreciably, and less, although considerable resistance to its disturbance by increase of volume.

Liquids, however, offer exceedingly slight, and sometimes immeasurably slight, resistance to change of relative position of their particles, which, therefore, move more or less freely among each other, according to the greater or less viscosity of the liquid. They thus offer little or no resistance to change of form.

Solids are composed of aggregated molecules existing in the same condition of equilibrium as is seen in liquids, and offering similar resistance to change of volume; but they differ from liquids in exhibiting resistance to change of form, which resistance can usually only be overcome by actual destruction of cohesive force. This peculiar condition is the result of that form of force which has been termed "polarity."

(7). These three forms of matter are not distinctly separated from each other, but the same substance may pass, by gradual change, from one to another of the several classes, and may, in its ordinary state, exhibit such physical characteristics as to make it difficult to determine to which of two classes it is to be assigned.

In addition to the above it may be added:

(8.) Solid bodies offer a resistance to change of form, which, within narrow limits, is proportioned to the magnitude of that distortion.

Beyond these limits the force producing change of form soon separates the atoms completely, by overcoming gradually the interatomic forces, and rupture takes place.

3. The last principle was discovered two centuries ago by that wonderfully acute philosopher, Robert Hooke, who published in 1678 his now well known law, "*ut tensio sic vis.*"

The first seven of the preceding principles embody the general theory of Roger Joseph Boscovitch, who first published it in an important treatise printed at Vienna in 1759.

Both of these early philosophers based their theories upon such unsatisfactory experiments as they were able to observe before scientific methods had begun to exhibit the exactness and the delicacy now characterizing them.

It seems equally remarkable that their deductions should accord so perfectly with later determinations, and that so little progress should have been made since, in researches upon intermolecular relations.

That portion of the theory of Boscovitch which supposes several alternations of attractive and repellant resultant forces, has received some apparent confirmation by experiment, but it is by no means proven. It would seem more probable that the attraction of cohesion, and the repulsive force of heat energy, are the two simple intermolecular forces which determine intermolecular distances.

Rankine's theory of molecular vortices affords a hint as to the possible action of heat here referred to.

4. It would seem very possible that phenomena apparently conflicting with this latter belief, will find explanation in molecular changes of position, rather than in the interaction of forces differing in nature, from those familiar to us.

In all familiar examples of solids the force of repulsion increases more rapidly than that of attraction as the molecules are forced to approach each other, and the reverse is observed as they separate. The molecules occupy, when undisturbed by external forces, positions of equilibrium which have been attained by passing over a range through which, at a constant temperature, attractive force has predominated, and the alternations referred to above, can, if observed at all, only be seen after compressing the mass and forcing the particles past this first position of equilibrium.

The other principles stated, if not absolutely proven by experiment, are at least rendered extremely probable, and are uncontradicted by any recorded phenomena.

Hooke's law has been proven sufficiently exact by numerous experimenters upon the tensile and compressible resistances of materials, and by Chevandier and Wertheim, and later, more fully, but not with more precision, by the writer, in a series of experiments upon torsional resistances, in

which the apparatus was made self-registering.*

5. We remain at present in almost perfect ignorance of the true nature and exact relations of the forces which are concerned in determining these physical conditions of matter.

So much as is known is, apparently, in conflict with every hypothesis yet proposed, in some essential point, yet we cannot resist the conviction that these forces are simple modifications of those most familiar to us; the attractive force being that of cohesion, and the repellant force being that of heat motion, while a third force, or third component of the one force, is that known as "polarity."

It would seem, from the experiments of Coulomb, Professor Henry, Plateau, and others, that the elasticity and resistance of solids are due, principally, to the action of molecular forces during changes of molecular grouping, rather than to changes of distances between particles. The latter has an exceedingly slight range, but, as shown by those experiments of Wertheim, which indicate an alteration of volume by tensile stress, an actual, though slight, change of atomic distances does probably take place.

It cannot be asserted that these experiments are absolutely conclusive on this point.

6. The experiments of Prof. Baden Powell upon the effect of heat in altering the breadth and diameter of Newton's rings, † are strongly confirmatory of the opinion, already expressed, that the repulsive force of the intermolecular spaces is that of heat motion.

7. The experiments of Dr. Andrews upon the "critical state" of substances passing from the liquid to the gaseous condition, and *vice versa*, are considered, by him, to indicate that those states are "but widely separated forms of the same conditions of matter," and that the one may be made to pass into the other without abrupt change.‡

M. Cagniard de la Tour made the earliest experiments in this field in 1822, and was closely followed by Faraday.

Dr. Andrews' more recent researches are probably the most complete and the most fruitful. His investigations of the phenomena accompanying the changes of carbonic acid, as to temperature and pressure, and particularly while passing through that phase of transition known as the "critical state," have thrown some light upon molecular relations.

The "critical state" is that condition of matter in which it exists when just passing from the liquid to the gaseous state, or the reverse, by a regular, as distinguished from the more familiar irregular process. It constitutes the "debatable ground" between these two states of matter, whence it is impossible to determine in which condition it should properly be considered.

It is found that, when just approaching this point, liquids are even more compressible than in the antecedent gaseous condition.

Water passes through the critical state at a temperature estimated at about 770 deg. Fahr. by M. Cagniard de la Tour, and at a pressure too high to be accurately measurable.

At this high temperature and pressure it dissolved the glass tubes in which it was attempted to confine it.

8. Dr. Andrews found that carbonic acid exhibited this gradual and regular change from the gaseous to the liquid condition at a much lower temperature.

The experiment of M. Tresca on the "flow of solids"‖ are exceedingly interesting and valuable in this connection, as lending confirmation to the views expressed by Dr. Andrews.

The phenomena of the critical state are considered by high authorities as strongly confirmatory of that portion of the Boscovitch theory which most requires confirmation.

9. After having passed from the gaseous to the liquid state, matter is found exceedingly difficult to reduce in volume. A pressure of one atmosphere produces, in the case of water, a decrease of volume of but *forty-six one millionths*.§

10. In liquids, attractive force makes itself observable, although the extreme mobility of their particles prevents the ready or accurate measurement of its value.

Professor Henry, who made the first attempt to estimate it, considers that the cohesive force of water is several hundred

* Journal Franklin Institute, April, 1873.
† Phil. Trans., 1834.
‡ Phil. Trans., 1869.

‖ London "Engineering," 1866-'67.
§ John Cantor, Trans. Royal Soc., 1762.

pounds per square inch. This considerable force resists change of distance between molecules, but does not perceptibly influence change of form, and we have, therefore, the curious fact to observe here, of the co-existence of cohesive force with almost perfect mobility of particles; the latter condition rendering the resistance to change of form very difficult of detection and measurement.

11. In the process of transition from the liquid to the solid state, in addition to the generally continued diminution of volume, molecular approximation, and the assumption of new positions of equilibrium by the particles, in consequence of the abstraction of heat, another, as yet unexplained, action occurs, which may be called, for want of a better term, *molecular polarization.*

This new force comes into play at a point which is definitely fixed, for each substance, on the scale of temperature, and although the resistance to forces tending to produce changes of intermolecular distances may be but little increased, resistance to change of form makes itself observable, generally suddenly, and solidification is produced by the fixation of molecules in definite relative positions.

The charcateristic which distinguishes the solid from the liquid state is the effect, apparently, of this force of "*polarity*," simply.

Dr. Henry remarks: "It is in accordance with the phenomena of cohesion to suppose that when a solid is liquefied by increase of temperature, instead of the attraction of the liquid being neutralized by the heat, that the effect of this agent is merely to neutralize the polarity of the molecules, so as to give them perfect freedom of motion around every imaginable axis." This author was probably the earliest to detect, and to state thus precisely, the part played by this force of polarity in molecular phenomena.

12. The cohesive force which makes its appearance when a gas becomes liquefied is probably considerably increased in all cases when solidification occurs; but the mobility characteristic of the liquid state is so perfect that it is difficult to make the comparison, and we, consequently, have scarcely any reliable data from which to estimate the value of cohesion in fluids. The most valuable are probably those of Prof. Henry*, already referred to, from which he estimated the cohesion of water to be nearly that of ice.

13. In the cases of some, and, probably, of many solids, the relation of these intermolecular forces becomes such that, if the force of polarity is overcome, and the molecules forced from the relative positions which they originally assumed, without, at the same time, changing their relative distances to such an extent as to destroy their tenacity, they may slide into new positions in which they will tend, under the action of this polarity, to remain permanently as before. The action here referred to is illustrated by some of Coulomb's experiments on torsion, by those of the writer on the same point, by M. Tresca's experiments on the flow of solids, and by the common methods of "squirting" lead pipe and of "spinning" brass.

In the experiments of Coulomb, a wire which had been twisted so far as to have taken a permanent set, was found to have its elasticity still unimpaired, and could be twisted as far, without taking a new set, as it could originally before taking the first. In some examples, several successive positions of set, with equal elastic limits, were found. Even a thread of clay, soft and plastic as it is, exhibits this peculiar action. The experiments of the writer on iron and steel $\frac{1}{8}$ths of an inch in diameter give precisely similar results.

These experiments are usually quoted in support of the Boscovitch theory of alternation of attraction and repulsion, but it may certainly be questioned whether the view just presented is not by far the more probable one—the successive sets being produced by successive renewals of the action of polarity, as the molecules were forced to move among each other without such increase of intermolecular distances as to destroy their cohesion.

14. In cases of true crystallization we have no means of determining whether the formation of the crystal, in its invariable and symmetrical form, is due to Prof. Henry's polarizing force, or to still another distinct force, or component of the one intermolecular action.

Since, however, it would be generally supposed that one force may produce both phases of polarization, the universally recognized "principle of least action" in nature suggests the belief that there is but one.

The phenomena of magnetism, and of

* Proceedings Am. Phil. Soc., 1844.

diamagnetism, are undoubtedly exhibitions of molecular action, under these intermolecular forces, but it remains to be determined whether they are, also, produced by the force under consideration.

The experiments of MM. Chedeville and Treve, at Brest, and of other experimenters, indicate, at least, some relationship between, if not the identity of, these forces.

15. It is sufficiently evident that, granting the relation of these several forces to be such as is indicated by what has preceded, the attractive, repulsive, and polarizing forces of matter may have any relation of intensity, and consequently, that substances may exist in very various conditions.

We may have a mass of matter, in which repulsion of any degree of intensity, may be recognized only as with the gases; attraction and repulsion may equilibrate each other, uniting to produce a mass resisting change of molecular distance, with any degree of force, and yet, in the absence of polarity, offering little or no resistance to change of form, as is the case with the mobile liquids. The addition of the polarizing force confers viscosity upon liquids, and this viscosity has every value until, as it becomes great in proportion to the intensity of the other forces, we find the mass rigid, and if cohesion is, at the same time, considerable, the body is hard. A body like the diamond would have great cohesion, and, relatively, still greater polarity; iron exhibits great cohesion and considerable polarity, at ordinary temperatures, polarity vanishing faster than cohesion, probably, when the metal is heated.

16. There are some remarkable, and still mysterious, molecular phenomena for which we have neither the space nor the data necessary to their discussion.

The most striking is what may be termed molecular friction. This peculiar phenomenon has been frequently noted, but does not appear to have attracted the attention or to have provoked the careful research that its possible importance should have prompted.

If a bar of steel is magnetized and demagnetized, it is noticed that it most readily accepts afterward the polarity first conferred upon it. What is known as "residual magnetism" is another method, probably, of manifestation of the same action. It is well settled that magnetic phenomena are phenomena of, or invariably accompanied by, molecular movement, and there appears in these cases, to be exhibited a kind of interatomic friction, which, producing a "set," prevents the return of the particles to their original positions, and allows the force of polarity to be most readily overcome in a definite direction.

The "fatigue" of metals, which has been so fully and elegantly investigated by Wohler,* may be an exhibition of the effect of similar causes. It may, however, be simply due to unequal tension, and the consequent gradual rupture, successively, of overstrained portions of metal, the work being thus thrown upon smaller and smaller sections of sound metal, until the whole becomes finally disrupted.

The determination of the effects of chemical changes upon molecular tensions presents a wide and, as yet, almost absolutely unknown field of research.

For one of the most complete and consistent theories of molecular physics which has been proposed, we are indebted to Professor W. A. Norton.†

17. It will require much additional experimental investigation, and far more carefully planned and systematic research than has been yet given to the subject, to furnish the basis for a perfectly satisfactory theory of the nature, and modes of action, of corpuscular forces.

If we may draw any conclusions from what is known already, we should probably infer that, when in the gaseous condition, the molecules of matter tend continually to separate, under the action of a repellant molecular force, which has greater magnitude as the gas is compressed.

As this compression goes on, either by the application of mechanical force, or by the abstraction of heat, a point is finally reached at which an equilibrium occurs between the forces tending to produce reduction of volume and those tending to expand the mass.

Any effort which may be made to destroy this equilibrium, and to increase the intermolecular distances, and, by the same action, to enlarge the volume, may be found, as in the case of water, to be resisted with some force, while an effort to produce a change of distance, by forcing the particles from their positions of equilibrium in the other direction, reducing the volume, may meet very great resistance. And while re-

* "Uder die Festigkeitsversuche mit Eisen und Stahl:" A Wohler, Berlin, 1870.

† American Journal Science and Art, 1872.

sistance to change of distance is observed, it may happen that the resistance to change of position, among the molecules in a group, may be, and often is, quite unobservable.

18. Abstracting heat still further, solidification finally occurs.

As, throughout the process of contraction, up to this point, the attractive force has gradually increased in its power of resisting disturbance of equilibrium and change of molecular distances, it would be anticipated that the solid would exhibit greater cohesion than the liquid. There is but little evidence bearing upon this point, and it will require extended and skilful, as well as patient, investigation in the field of Prof. Henry's labors, to furnish what is needed. What we have learned indicates that this increase does occur, and that its amount is very great.

19. The simple increase of cohesive force, where the distances between the molecules are still so immense in comparison with the magnitudes of those molecules, would not be expected to give increased elasticity of volume. On the contrary, during the change from the gaseous state the loss of elasticity of volume has been a marked characteristic.

(It is considered by some philosophers to be well ascertained that the radius of molecular action is less than one five-millionth of an inch in some cases*, and that it probably does not equal one two-thousandth of an inch in any instance†. At least one writer considers that the molecule has an orbital radius not exceeding 1-250,000,000th of an inch‡. The existence of animal organisms as small as 1-250,000,000th of an inch in length indicates that even these figures are not probably too small.)

20. An unavoidable inference from the language of authorities most frequently quoted is, that elasticity of form—the quality of which the so-called elasticity and the resilience of solids is a consequence—results from the existence of a property in solid matter by which change of distance between molecules may occur to a marked extent without rupture.

This, if true, would indicate elasticity of form to vary with elasticity of volume.

This, we should infer, may be a mistake, the elasticity of volume being probably less in the solid than in the liquid, while elasticity of form is absent in the latter.

If it be the fact that the elasticity of form and the resilience of solids are not due to elasticity of volume, primarily, we are justified in attributing them to the property of pliability, produced by the comparatively wide range of intermolecular movement permitted by the force of polarity. In examples of great elasticity, it may have an intensity, small in comparison with that of the other forces acting in the mass, and, at the same time, it, or the cohesive force, or both, may vary at a less than ordinary rate with a given change of distance.

21. We have followed what can be considered as scarcely more than a train of hypotheses, but it is evident that the faint light which has been thrown upon the subject exhibits, at least, a probability that they approximate with some degree of closeness to the truth.

We may deduce from what has been stated, finally, that it is extremely probable that the contraction in volume, of a solid, by approximation of molecules, will increase the absolute strength while decreasing the viscosity of the body, and, as a consequence, diminishing the resilience, by contracting the elastic limits. The mass might have a higher modulus of elasticity, and higher tenacity, but would more readily yield under a shock or a blow.

22. We should expect these changes in metals to be most marked within ordinary limits of temperature, in the cases of those metals which have lowest temperatures of solidification, since in such examples the complete change from absolute mobility to perfect rigidity is comprised within the least range of temperature.

23. All other things being equal, since lowering the temperature reduces the mobility of particles, and increases the viscosity of the metal, we should anticipate that the greater toughness of the material at the higher temperature, while in the solid state, would not only exhibit itself in greater resilience, but would also modify the character of the fracture, when ruptured by external force, making it less "short" and glass-like—wherever the substance possessed anything of the characteristics illustrated by Coulomb's experiments, noted above—at a high, then at a low heat. The fracture would be expected to appear "fibrous" and "thready" when, as in ordinary wrought iron, foreign substances present or varying quality of metal should produce in

* Wartman. † Robison. ‡ Gaudin.

adjacent parts unequal "drawing down" at the higher temperature.

24. Where, as in iron, the change from the liquid condition through the pasty, semi-fluid welding state, to the condition of comparative brittleness at ordinary temperatures, has been a somewhat regular one, it would be anticipated that the change might continue with still further decline in temperature. It would not appear unlikely that such change might progress indefinitely, or until resilience was absolutely destroyed by the approximation of molecules, and the coincident fixity due to a maximum intensity of polarity.

Where the body has sensible viscosity and considerable resilience, it would be expected that, if broken suddenly, as by a quick jerk, its fracture would be complete before the particles, retarded by inertia and by molecular friction, could have time to shift their positions, while, when slowly broken, a considerable amount of motion might occur before rupture could be completed.

In the former case, the appearance of the break and the diminution of section would be characteristic of tough, and in the latter, they would apparently indicate brittle, material.

25. Such being, not improbably, a statement of the general effects of changes of temperature upon matter, it remains for the engineer to determine, by experiment, how fully the most generally useful metal, iron, presents an example of these effects, and how far they are modified by differences of chemical constitution and of physical condition.

The most interesting and instructive experiments which have yet been made are those of Fairbairn, Kirkaldy, Professor Johnson; of a committee of the Franklin Institute; of a committee appointed by the King of Sweden; of Brockbank, Joule, Sandberg, and Spence.

26. Tredgold, the celebrated engineer, whose intelligence and experience have given his published opinions very great weight, believed that any increase of temperature would diminish the tenacity of metals.

Dr. John Percy, on the contrary, with probably the majority of engineers, believes the opposite to be the effect, basing the belief upon the well-known fact that accidents more frequently occur from fracture in cold than in warm weather. So common is this belief, that the statement recently made, that the real effect of decrease of temperature, other things being equal, may be to increase tenacity, has been received with very general distrust.

27. The magnitude of a change of tenacity arising from simple approximation of molecules, and consequent increase of cohesion, could not be expected to be very great, since this change of distance between adjacent particles is but about seven one-millionths of its ordinary value for a range of one degree. Were the tenacity to vary as the square of the distance, the consequent variation would be but one and a half per cent., and would be but two per cent. were it to vary, within this range, as the cube of the intermolecular distances for a range of one thousand degrees.

28. In comparing the conclusions deduced by the several experimenters, of whose labors the following is an abstract, some evident misconceptions will be noted, which plainly arise from the very common error of attempting to estimate the strength of materials from experiments in which they are tested by shock, forgetting that a material may be immensely strong and yet, if brittle, non-resilient, may be readily broken by a blow which would leave uninjured a less tenacious but more ductile specimen.

It has evidently been quite unsuspected by the majority of experimenters and of writers on this subject, that change of temperature may, while producing an alteration of the cohesion of metals, effect a directly opposite change in its ductility, and that, consequently, the substance may exhibit greater tenacity, and may, therefore, better resist a steady strain, while at the same time its ductility may be so greatly decreased by the same cause as to greatly lessen its resilience, and thus, though stronger, it may be less capable of resisting shocks.

29. A committee of the Franklin Institute, of the State of Pennsylvania, consisting of Professor W. R. Johnson, Benjamin Reeves, and Professor A. D. Bache, were engaged, during a period extending from April, 1832, to January, 1837, in experiments upon the tenacity of iron and of copper under the varying conditions of ordinary use.

The effect of change of temperature upon those metals was investigated with equal intelligence and thoroughness, and most valuable results were obtained.

30. Upward of one hundred experiments upon copper, at temperatures ranging from the freezing point up to 1000 deg. Fahrenheit, exhibited plainly the fact that a gradual diminution of strength occurs with increase of temperature, and *vice versa*, and that the change is as uniform as the unavoidable irregularities in the structure of the metal would allow.

The law of this variation of tenacity, within the limits between which the experiments were made was found to be closely represented by the formula,

$$D^2 = CT^3$$

i. e., the squares of the diminutions of tenacity vary as the cubes of the observed temperatures measured from the freezing point.

31. The committee, in the course of their exceedingly judicious and complete series of deductions, say:*

"The temperature of no tenacity is generally supposed to be that at which the fusing point of the given substance is placed, and the point of maximum tenacity ought, upon general principles to be found at the point at which least heat prevails, that is, at the natural zero or point of absolute cold, if such a point exists in nature.

"Between these two extremes, it might be supposed that the tenacities of different substances, particularly such as are capable of passing immediately from the solid to the liquid state, would be found to obey certain laws.

"As the total cohesion, at the maximum, would present to a mechanical agent tending to overcome it the whole of its resistance, and as, at more elevated temperatures, a part of that tenacity would be overcome by heat, and the rest would be destroyed by the mechanical force, it is evidently a question of experiment to decide what relation the two forces have to each other, at the temperatures between the two extremes to which we have just alluded.

"To decide the theoretical question, or, in other words, to deduce from the experiments a law which might be expressed in an abstract form, corresponding to all the possible phenomena, would require a state of the materials different from that usually found in commerce or employed in the arts.

"It would also, as we have seen, require a knowledge of that about which philosophers, no less than practical men, are far from being agreed, namely, the point of absolute cold."

32. The Committee do not fail to observe that there are indications that the curve, of which their formula is an approximate equation, has, very probably, a point of contrary flexure at a temperature somewhat below the highest at which they were able to experiment, or, near the point at which one-half the tenacity of the material is destroyed.

This inflection of the curve, which indicates that no parabolic formula can be made to represent, accurately, the change of tenacity with varying temperature, is very clearly exhibited in the curve laid down from the experiments on the strength of wrought iron, which were next made by the Committee.

33. These experiments were 73 in number, at temperatures between 212 deg. and 1317 deg. Fahr., and comparisons were made with the strength of the same bars, at ordinary temperatures, as determined by 163 experiments.

The bars were generally broken at sections reduced by the file, and the results give but little indication of the effect of change of temperature upon the resilience and extensibility of the metal; but they afford most interesting, accurate, and valuable measures of the effect of heat upon tenacity.

34. It was this investigation which first disclosed the remarkable anomaly of the existence of a point in the scale of temperatures, usually, if not invariably, considerably above that of ordinary temperature, at which the metal exhibits a maximum of tenacity.

35. By heating a number of bars to 572 deg. F., which was found to be very nearly the average temperature of maximum strength, and breaking them at that temperature, it was found that a mean of experiments on the best qualities of rolled iron, gave this maximum as 15.17 per cent. higher than the tenacity of the same samples at ordinary temperatures.*

The irregularity of structure of specimens tested was found to cause an irregular variation of strength amounting to 10 per cent.

36. Taking 80 deg. Fahr. as a standard temperature, the committee discovered that

* Report of Committee, p. 74. Phila.: Merrihew & Gunn, 1837.

* Report of Committee; p. 213.

the fifth power of the diminution of tenacity from the maximum, determined as just stated, varied as the thirteenth power of the temperature above 80 deg. Fahr.,* or,

$$D^5 = C\,(T-80^\circ)^{13},$$

where D = diminution of tenacity, T=temperature, C = a constant.

At the temperature of about 400 deg. and 1200 deg., points of departure from the curve took place as already stated, the deviation from the law expressed by the formula becoming quite marked.

37. The committee made a series of experiments upon the effect of annealing in altering the tenacity of the metal.

They found no measurable change in specific gravity, except with specimens which had been hammer-hardened. The tenacity was diminished to an extent which follows very closely the order of temperature at which annealing was performed, and this loss varied from 2½ per cent., when annealing was performed at low temperature, to 46 per cent., when the metal was annealed from a bright welding heat.

The results seem quite variable, but, at about 1100 deg. the losses had a mean value of about 15 per cent., while, at a welding heat, they averaged nearly 25 per cent.

In testing old boiler plate, a loss was supposed to have been proven, which was attributed to this cause, and which amounted to about 6 per cent.

Unfortunately, the experiments of the committee do not afford the data requisite for determining the resilience of these specimens, and we are unable to learn whether the observed depreciation of strength was accompanied, as we should expect, by an increase of ductility.

38. No experiments were made at temperatures less than 32 deg., and it remained for further research to determine the behavior of iron at exceptionally low temperatures.

The work of the committee was most skilfully performed, and most conscientiously recorded and reported. Together with the equally exhaustive and thorough work of the full committee on steam boiler explosions, of which this was a part, it affords most valuable and reliable additions to our experimental knowledge.

These were the first experiments ever made on an extended scale, and the determination of the area of fractured section, the measurement of elasticity, of latent heat, specific heat, the conducting power, and other properties of iron and copper, were made with much greater care than could have been expected at that early period. The committee was engaged in the work nearly five years, and the expenses incurred were defrayed by the United States Treasury Department.

39. A somewhat similar series of experiments was made by Sir Wm. Fairbairn upon rolled iron*, and the same behavior was noted, under varying temperatures, as was so well shown by the earlier researches of the committee of the Franklin Institute.

The tenacity of Staffordshire boiler plate was examined at temperatures varying from 0 deg. Fahr., to a dull red heat—probably 1,000 deg. Fahr.

This iron is not of high quality, and some marked deviations were observed from the general direction of alteration of strength.

The tenacity of the specimens gradually increased, as the temperatures rose from 60 deg. to 395 deg. Fahr., and thence diminished, until, at a red heat, the strength became reduced to the extent of 25 per cent.

The tenacity recorded at 0 deg. Fahr. was, however, 6 per cent. greater than the mean noted at any other observed higher temperatures, but not greater than that of individual specimens.

40. Other experiments were made upon rivet iron, which was necessarily of better quality than the Staffordshire plate.

The tabular statement of the results shows a gradual and quite regular increase of tenacity from 60 deg. to 325 deg. Fahr., the strength being given at 62,816 and 84,046 lbs. per sq. in. at those points respectively —a difference of 30 per cent. The tenacity then diminished as temperature rose, becoming reduced to 35,000 lbs. per sq. in. at a red heat.

The strength at 30 deg. Fahr., was slightly greater than at ordinary temperatures, the figure given being 63,239 lbs. per sq. in.

41. Experiments made by Fairbairn on the effect of temperature upon cast iron give less uniform, but still instructive results.†

* Ibid. p. 218.

* British Association Report, 1856.
† British Association Reports, vol. 6, 1837.

With No. 3 iron very unsatisfactory and contradictory results were obtained, in consequence of the irregular character of its structure and chemical constitutions.

Coed-Talon iron No. 2 exhibited continual decrease of transverse strength as the temperatures increased. Both cold and hot blast irons were experimented upon, at temperatures ranging from 26 deg. to 190 deg. Fahr., with the following results:

Cold blast, at 26 deg. and at 190 deg., decreased in strength in the proportion of 874 to 743. Hot blast, at 21 deg. and 190 deg., decreased in strength in the ratio of 811 to 731.

It should be remarked that these experiments were made in the early days of hot blast, when the differences in the character of hot and of cold blast iron were more marked than at a later date, when the management of the former had become more generally and more perfectly understood.

42. Mr. Fairbairn remarks:* "On the whole, we may infer that cast iron, of average quality, loses strength, when heated beyond a mean temperature of 120 deg., and that it becomes insecure at the freezing point, or under 32 deg. Fahr."

He supposed that the fact that, in some experiments, he found No. 3 iron to increase in strength with rising temperature, is due to its great "irregularity and rigidity."

He also remarks† that "The infusion of heat into a metallic substance may render it more ductile and probably less rigid in it nature, and I apprehend it will be found weaker and less secure under the effects of a heavy strain."

43. The experiments of Roebling referred to in his report to the officers of the Niagara Falls Suspension Bridge Co., in 1860, do not throw much light upon the question under consideration.

Mr. Roebling's remark that metal, of as good quality as that upon which he experimented, would be "safe at the North pole,"‡ may justify the inference that he supposed that such iron would, at least, not lose tenacity when very cold.

44. David Kirkaldy, of Glasgow, in December, 1860, while conducting one of the most extended, accurate and well arranged experimental inquiries into the value of the tenacity of iron and steel that has been made,* took occasion to examine the action of frost upon them.

"A bar of Glasgow B, best, ¾ in. diameter, was converted into ten bolts, in the ordinary way. Six were exposed all night to intense frost, and tested in the morning with the thermometer at 23 deg. Fahr. The others were kept in a warm place, and carefully protected during testing. Three were tested with gradual, and seven with sudden strains." "When the strain was gradually applied, there was very little difference between the specimens tested in the ordinary condition and the two that were frozen; the former bore 55,717; the latter, 54,385, or 2.1 per cent. less. The difference under sudden strains is somewhat greater, viz., 3.6 per cent. less when frozen." This iron was of good quality, and Kirkaldy remarks that "had it been of a coarser description, the difference, when frozen, might have been much greater." He concluded† that "the breaking strain is reduced when the iron is frozen; with the strain gradually applied, the difference between a frozen and an unfrozen bolt is lessened as the iron is warmed by the drawing out of the specimen."

Kirkaldy noticed that "The amount of heat developed is considerable when the specimen is suddenly stretched"—an important circumstance which had previously escaped the observation of experimenters.

45. The subject was debated at some length at meetings of the Manchester Literary and Scientific Society, some two years ago, and experiments were described, which afforded data of value and interest.

Mr. William Brockbank described his experiments, made for the purpose of determining the effect of cold upon the cohesion of cast iron. Using a mixture of several irons of quite different qualities (Cleator red hematite, Pontypool and Blaenavon cold blast and Glengarnock hot blast irons, with scrap added), he found a perceptible decrease of strength with decrease of temperature. He noted a similar effect where wrought iron was used. The experience of well-known ironmasters was adduced in corroboration of these conclusions, the examples being, usually, instances of breakage by *shock*. The conclusion of the experimenter‡ was that "bar iron, boiler

* On the Application of Cast and Wrought Iron to Building Purposes: London, 1844; p. 66.
† Journal Franklin Institute, 1840; vol. 25. p. 58.
‡ Journal of Franklin Institute, 1860; vol. 40, p. 361.

* Experiments on Wrought Iron and Steel; David Kirkaldy, Glasgow, 1863; p. 85.
† Ibid. p. 95.
‡ Nature, 1871.

plate, wire billets and rails are most materially weakened by the action of intense cold, losing their toughness, becoming quite brittle under sudden impact, and having their structure changed from fibrous to crystalline."

46. Sir William Fairbairn stated the results of his experiments, substantially as has been already given, attributing the more frequent breakage of wheel tyres in cold weather, to which allusion had been made, to unequal strains due to shrinkage, rather than to loss of tenacity.

47. Dr. Joule gave an account of his own experiments, upon a smaller scale, made at temperatures of 12 deg. and 55 deg. Fahr., with weights applied without shock. The result indicated an increase of strength at the lower temperatures, in the proportion of 58⅓ to 59 5-6, or 2½ per cent., as a mean of 12 experiments. Experiments, 41 in number, in which the breakage was produced by shock, gave the opposite result. These experiments were made upon large steel needles, and upon cast nails. They have been sometimes ridiculed as too insignificant to afford valuable evidence, but, insignificant as they may appear, and roughly made as they undoubtedly were, they are valuable as giving corroborative evidence of the fact which has already been quite well proven, that decreasing temperatures, in general, produce increased strength, but decreased elongation and resilience.

He concludes that "frost does *not* make either iron (cast or wrought) or steel brittle, and accidents arise from the neglect of the companies to submit wheels, axles, and all other parts of their rolling stock to a practical and sufficient test before using them.

(To be continued.)

EXPERIMENTS ON THE ACTION OF DYNAMITE.

From "Iron."

1. The experiments undertaken at the central depot of the French Saltpetre and Powder Works, in order to estimate the relative force of different explosive bodies, lead to results capable of throwing light upon some obscure points in the effects produced by the explosion of dynamite.

When dynamite is ignited by violent concussion, such as that occasioned by the detonation of a strong primer, it explodes, even in the open air, and if confined, produces so great an effect that one part of nitro-glycerine does the duty of ten parts of gunpowder. If inflamed in any other manner without percussion it burns quietly in the open air, and if confined, may give rise to an explosion. This explosion, however, whatever may be the temperature and the pressure to which the charge is submitted, is of a quite different character from the one above-mentioned. Instead of detonation, or explosion of the second degree, the effect being such that one part of nitro-glycerine corresponds to two of powder.

These results have been obtained by finding the bursting-charges necessary to fracture cast-iron bombs of the same resisting power. These bombs are closed with screw-stoppers, through which plays an isolated wire, so that a small Abel's capsule can be let off in the interior.

The bursting-charge of fine sporting-powder is about 16 grms. With No. 2 dynamite of Vouges, containing 50 per cent. of nitro-glycerine, detonated with a Gevelot primer (containing 0.25 grms. of fulminate), the bursting-charge is about 3.50 grms. In place of the primer, 1 grm. of powder was used. In this case the bomb was successively charged with 4, 6, 10, and 15 grms. of dynamite, and only burst with 16. The dynamite, therefore, produced in this case the same effect as powder, and as it contains 50 per cent. of nitro-glycerine, one part of the latter is equal to two of powder.

In another series of experiments, in place of augmenting the charge of dynamite, the constant weight of 4 grms. was placed in the bombs (which with a detonator would be sufficient to burst them), and the accompanying charge of powder was successively increased. Along with the 4 grms. of dynamite, 5, 8, and 10 grms. of powder were successively used, and the bomb did not burst until 12 grms. were employed. Thus dynamite at 50 per cent. again proved itself equal to its weight of powder. It was found in every case that the dynamite placed in the bomb was entirely consumed. The question arises what would be the effects of a dynamite richer in nitro-glycerine?

The following experiment is decisive:—A dynamite at 90 per cent. of nitro-glycerine, fired with a primer, burst the bomb with a charge of 1.80 grm. But a charge of 3 grms. of the same kind of dynamite with 3 grms. of powder took no effect.

The trial-bombs being able to bear a pressure of at least 100 atmospheres, and the temperature of the flame of powder being at least 3,000 deg., it may be affirmed, within the limits of practice, that:—

1. Dynamite accidentally ignited and being, *e g.*, in the midst of a conflagration, will not detonate.

2. It may produce an explosion of the second degree analogous to that of powder.

3. The maximum intensity of such explosion, producible when the enclosing space offers a great resistance, is such that 1 part of nitro-glycerine is equal to 2 parts of powder.

II. The following experiment shows that dynamite can be caused to detonate solely by means of percussion of sufficient intensity. The authors used for this purpose a dynamite at 50 per cent., prepared with finely-divided silica, so as to yield a matter of low specific gravity. The charge being ignited with a primer, the bomb was burst with 4 grms., but only when the charge was wrapped up in paper placed around the primer. If the dynamite is placed loose in the bomb, even though the primer is placed in the middle of the matter, the charge may be raised as high as 12 grms. and beyond without rupturing the shell. It is clear that in the first case we obtain detonation, or explosion of the first degree, but in the second merely explosion of the second degree. The primer, therefore, along with the dynamite, can produce both phenomena according to circumstances. In the first experiment the dynamite, being kept in its place by the paper, undergoes the full action of the shock. In the second it is scattered by the shock, and is only ignited by the burning gases. This experiment succeeds only with pulverulent dynamites of a low specific gravity. With the ordinary dynamites, of a dense and plastic nature, the bursting ensues with the same charge, no matter how it be placed, provided that it surrounds the primer. The following fact, well known to miners who use dynamite, fully proves that the intensity of percussion is the determining cause of the explosion. When the primers are insufficient, and often miss fire, this evil may be remedied by strengthening them, *i. e.*, doubling the metal which forms the tubes. The authors have verified this fact with different explosive matters, one and the same primer producing, or failing to produce, the detonation of the dynamite according as it was encased in a tube more or less resistant.

III. The fact of two orders of explosion so different in intensity being produced by dynamite, enables us to understand how matters of this nature, containing one and the same amount of nitro-glycerine, may have widely differing bursting powers. The authors have found, for instance, in dynamites of 30 per cent., the explosive power varying in the ratio of 1 to 2, according to the absorbent matter employed. A dynamite is stronger the more easily it is ignited by the shock. When the ignition is easy, the effect of the percussion produced by the primer is immediately transmitted throughout the entire mass. This is the case with dynamites prepared with quartz sand. On the contrary, when the substance is not easily ignited, the action is propagated incompletely; a part only of the mass detonates, the remainder exploding in the second degree only. This effect is obtained with dynamites prepared with plastic materials like ochre. These facts are plainly shown by the following experiment, in which the double effect is manifested with one and the same charge of dynamite. Operating on the dynamite at 50 per cent., 4 grms. of which were sufficient, with detonation, to burst the bomb, the authors placed 2 grms. in a piece of paper surrounding the primer, the residue of the charge being spread loose in the bomb. In this case 4 grms. (2+2) and even 6 grms. (2+4) are insufficient. The charge must amount to 8 grms. (2+6) to burst the shell. The 2 grms. folded up around the primer acted by detonation; the 6 grms. lying loose by explosion of the second degree, and these two combined actions effected the rupture. Thus the detonation of one portion of dynamite does not necessarily induce the detonation of an adjoining mass, though such mass may be ignited and produce an explosion of the second degree. The propagation of the action is the more difficult in proportion as the dynamites are harder to ignite. The authors conclude that dynamite can, according to circumstances, produce explosions of totally different order. Percussion alone, *so far*,

appears to them capable of producing explosion of the first degree, or detonation. The pressure and temperature to which the matter is submitted do not modify the conditions of the phenomenon.

This paper calls for a few remarks. That the nitriles, whether nitro-glycerine, nitrocellulose, commonly called gun-cotton, or nitromannite, are, under different circumstances, capable of exploding with very different degrees of intensity is an incontrovertible fact. That they may be brought to explode with their maximum force, or to detonate, by the use of a fulminating primer, is also certain. But the maximum and minimum force, called by Messrs. Roux and Sarrar explosions of the first and second degree, seem rather to be the extremes of a possible series of effects than two unconnected phenomena. If nitro-glycerine is capable of performing under certain circumstances twice, and under others ten times, the duty of powder, it is very probable that under other sets of conditions it must explode with immediate degrees of force. Farther, whilst the authors have shown—what was well known before—that the nitriles can be made to detonate by means of a primer, they have not failed to prove that they cannot detonate under other circumstances. Facts show quite the contrary. In Llanbenis case, where two kegs of nitro-glycerine exploded "spontaneously" in the carts conveying them to the slate-quarries, there was no primer concerned. Yet the fury of the explosion proved that it must have been one of the "first degree." In the Glasgow Water Works case, when some men, taking shelter in a hut, kicked an emptied nitro-glycerine can, with deadly result, there was no primer. Yet the havoc wrought by a mere film of nitro-glycerine adhering to the inside of the can quite forbids us to think of anything less than detonation. Precisely similar is the case with gun-cotton. It was declared incapable of detonating—indeed, of exploding at all—without a primer. Yet in the Stowmarket case, the gun-cotton in the packing-house evidently exploded with its maximum intensity, the result being in respect to the quantity far greater than of the first explosion in the magazine. Had the whole of the material stored there detonated, it is probable much of the town would have been levelled.

Messrs. Roux and Sarrar show that a heat of 3,000 deg. did not cause nitro-glycerine to detonate. But the heat they thus applied was but momentary. Now, the respective effects of momentary and prolonged heat upon the nitriles differ remarkably. The author has known pure gun-cotton (trinitic cellulose), shut up for some hours in a "water-oven," where the temperature never exceeded 260 deg. F., to ignite with a feeble explosion. A portion of the same sample placed in an open tube, and rapidly heated, did not explode before 350 deg. F., and a third portion dropped into a tube at that temperature required a farther rise of 10 deg. F. before it exploded. Certain experiments point to the conclusion that gun-cotton, and doubtless the other nitriles, if gradually heated to near its ignition-point, may detonate on coming in contact with a spark or receiving a shock. We must remember that even nitrate of soda—a substance which, when thrown into a furnace, merely causes deflagration—occasioned in the Gateshead and the New York cases phenomena which cannot be called anything other than explosions.

ANCIENT CONSTRUCTION.

From "The Engineer."

Mass was the predominant feature of ancient constructions, and clay, earth, bricks, and stones, the principal materials. The introduction of the arch or vault was one of the earliest substitutions of the hollow for the solid. If a solid massive square pillar have the middle portion cut out and an arch turned over the top, there is so much of the original mass removed, and a new style of construction, so to call it, introduced. It has been generally admitted that the invention of the arch is due to the Romans, yet there can be very little doubt but that the Assyrians were thoroughly acquainted with it, although clay in some shape or another constituted almost their sole constructive material. This formed the nucleus of the enormous artificial mounds which that people were fond of raising on which to erect their palaces, citadels,

and other commanding buildings. Instead of excavating foundations upon which to build, an artificial foundation was raised and the superstructure placed thereon. Modern works are now conducted on a scale so gigantic that we are pretty well accustomed to immense shifts of earth; but mechanical appliances are at our command which were unknown to our predecessors, who used neither wagons nor barrows, but hand labor only in its simplest form. In the erection of the artificial mounds to which we have alluded, the Assyrians were not in the habit of using the clay at random, but mixed and prepared it with great care, so that it showed a uniform section everywhere when cut. It was completely free from all stones and foreign bodies, and closely resembled in its consistency the best modern puddle. This material is now in numerous instances giving way to concrete, which promises fair to be to us what the clay and bricks were to the ancients. In works of a character similar to the Thames Embankment the quantity of concrete used in foundations and backing is something enormous.

Explorations at Nineveh have shown that except for paving purposes stone rarely entered into the construction of the walls and buildings. They consisted of clay only, which had evidently been moulded in the shape of bricks, and put together without the aid of mortar or cement of any kind. In the few examples in which stone was found to be employed the joints were made in the same manner, that is, by simple juxtaposition. Mortar and cement appear to have been rarely or never employed. The size of the stones was considerable, so that mere weight would, to some extent, render superfluous the employment of any adhesive substance at the joints. But this was not the case with the bricks, which were nearly of a square form, 1 ft. 4 in. on the sides by 2 in. in thickness. The question which remains unsettled is, in what degree of consistency were these bricks at the time they were put together? Were they sufficiently plastic to adhere together, or were they wetted before being used, so as to soften the surfaces merely which were in contact? Upon this supposition there would be an appreciable difference between the appearance of the body of the bricks and that of the joints, which does not exist. There is, nevertheless a slight difference in color at these points, which looks like lines. The Assyrians had two varieties of baked bricks; the one was regularly shaped with parallel faces, and the other of a trapezoidal form. These latter were intended for arches or vaults, and the inclination of the sides varied with the position which the particular brick was intended to occupy in the curve. The dimensions and proportions of the Assyrian bricks differ from those of modern manufacture. Those employed in paving were of two sizes. One class was 1 ft. 4 in. by 1 ft. 4 in., by $2\frac{1}{2}$ in. in thickness, and the other 13 in. by 13 in. by $4\frac{1}{2}$ in. thick. A peculiar feature in these old bricks is that they are with few exceptions covered with inscriptions in the cuneiform character. Two remarkable features in the construction of ancient cities were, first, that either the diagonals or the direction of the sides pointed exactly towards the cardinal points, and, secondly, the enormous thickness of the walls of the principal buildings. It is probable that astronomical reasons dictated the former of these, and climatic exigencies the latter. In the case of Nineveh there can be little doubt of this, as the Assyrians were celebrated for their skill in astronomy, and their partiality for the science. The thickness of the internal walls is scarcely ever less than 10 ft., and that of some of the external varies from 16 ft. to 25 ft. Some consideration must be given to the fact with regard to the thickness of the walls, that the mode of building them with bricks merely dried in the sun required this dimension to be disproportionately great.

In the building of their domes and vaults the Assyrians employed a more brittle description of brick than in their walls and pavements, and the joints were made by grouting them with semi-fluid clay. The voussoir shape of these bricks proves that the theory of the arch must have been known at that time, and some considerable progress made in the preparation of artificial stones. There is no evidence of timber being employed as a material of construction by the people under notice. It was used only in small quantities, and for the purposes of ornament. It seems that iron was altogether unknown as a constructive material. Copper was turned to account for the pivots or hinges of doors, and lead was also rendered serviceable. Enamelled bricks were common, and stucco was largely employed, as with us, for the double pur-

pose of protecting the brickwork from the effects of the air, and hiding the roughness of the surface. There is one ceremony which appears to have existed at the time of the Assyrians, which is common to modern times as well. It is that of laying the first or foundation stone of a building. A recent French explorer, M. P. Place, discovered in a layer of fine sand underneath one of the monoliths of the gates of Nineveh, a variety of different objects in marble, agate and cornelian, which were cut and engraved, and were, moreover, all pierced with a hole, as if they had originally formed part of a bracelet or necklace deposited at the laying of the stone as coins are deposited with us. While well versed in the practice of earth work, brick work, and even masonry, the Assyrians were totally ignorant of the art of construction considered in the light of an assemblage of pieces of timber or iron. They could heap up materials so as to cause the structure so composed to resist any outward force by its sheer weight or inertia, but they knew nothing whatever of the distribution of pressures, or how to proportion a structure so that it should be equally strong in all parts. Both the labor and the material were too abundant to call for economy in either one or the other.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—A regular meeting of this Society was held at the rooms in New York, March 19th, 1873.

Joseph Whitney, C. E., of Cambridge, Mass., presented the subject of "Leakages in Water Pipes," illustrated by specimens of defective water pipes from the Cambridge Water Works.

He desired to make a simple statement of his own operations and experiments. The great and growing increase in the consumption of water is a matter of the first importance in the management of water-works. Scarcely a report relating to water-works is issued which does not refer to it—and as something quite unaccountable; still no systematic effort is made to ascertain its cause.

Some years since his attention was called to the subject in Cambridge, where, for three years preceding, the water pressure had been growing less, thus causing much inconvenience and insecurity in case of fire. This was ascribed to the great number of users from one main, an eight-inch pipe. In a particular house the water scarcely rose to the second story—at night or day. After inquiry, a series of observations were made, with siphon pipe and pressure gauge, to determine the cause. These were made in the morning, when the consumption was nearly nothing, and in one case, by shutting off certain sections from the main, say a four or six-inch pipe, a large leak was revealed where the pipe, laid in a street filled with oyster shells, had parted. In another case, when the gate was closed, the water in the siphon at once rose 16 ft.—equal to about two stories of an ordinary house—the pipe, about 600 ft. long and laid upon a manche, was examined and the leak found in a joint, where the two parts had been entirely separated by a settlement of one section. These and other leaks, detected similarly, were closed, and thus, without any increase of size in the main, an additional head was secured of 35 ft., which gave a full supply to each house in that locality.

Observations were afterwards made upon the water in the reservoir in the night time, which showed still a leakage. By continued experiments upon the pipes throughout the city, nearly two hundred leaks, of from 1,000 to 2,000 gallons each per hour, were found. The necessary repairs were made, and thereby the average daily consumption per head was reduced from 85 to 35 gallons, which is not more than one-half that in most cities.

Leakage of this character may exist a long time without being known. Thus it may start when the water is first let on, and the water find a passage through some blind channel into the sewer; it will not be seen at the surface unless this upward and outward is the easiest course.

It is quite probable that this subject concerns other cities than Cambridge, and furnishes a satisfactory reason for the great increase in the consumption of water, and the corresponding growing demand for supply, which more or less embarrasses public authorities.

It is said that in the city of New York the consumption is about 100,000,000 gallons per diem; if so, he was sure at least 50,000,000 were wasted through unrecognized leaks into the sewers, and surrounding rivers. In Boston more than 17,000,000 gallons are supplied, where 8,000,000 should suffice.

It is a fair presumption that one-half these great amounts—being but waste—and its corresponding cost in the construction and operation of water works, may be saved; surely, examination, complete and exhaustive, should be made to determine whether this is presumption or fact.

Thomas F. Rowland, M. E., of Greenpoint, N. Y., presented a paper on the "Adaptation of Mechanical Power to the Work of Charging and Discharging Gas Retorts"—illustrated by a large working model of machinery for the purpose; by which it is proposed to take the coal from a pocket outside of the retort house, size, mix, transport and deposit it in proper quantities in the retorts, and afterwards discharge therefrom the resulting coke into the coke barrows.

The apparatus consists—first of an iron car, which traverses the retort house in front of a bench upon a railroad of 12 ft. gauge, and carries the mechanism for charging and discharging; and second, a series of buckets, which, suspended from an overhead or "pendent railway," conveys coal to the charging apparatus.

The iron car—about 14 ft. sq.—is propelled by an engine and boiler placed upon it, which also drive the machinery carried. Midway on the car the meter is located which receives the coal from the buckets and deposits it in the charger.

The meter is a horizontal cylinder divided lon-

gitudinally into three compartments or cavities—such that each will contain enough coal for one retort. It revolves intermittently at the base of a hopper or "coal pocket," which receives the coal from the buckets—each cavity therein being in turn filled with coal and emptied by discharge into shutes, severally in communication with the three scoops of the charger. These shutes are placed one above the other, and as the meter revolves, are automatically opened and closed, so that the coal is discharged into each in succession. The edges of the meter cavities and of the throat of the "coal pocket" are armed with hard, sharp steel blades, to cut or crush fragments of coal which, lodging between the surfaces, otherwise might clog the machine.

The "charger" is a carriage traversing the top of the car transversely; its three scoops are placed one above the other at distances corresponding to the vertical measure between the retorts—they are D shaped, like the retorts, and have movable bottoms. When the scoops are filled by a transverse movement of the carriage, they are thrust forward into the retorts; the motion being reversed, the bottoms and then the scoops are withdrawn; thereby the coal is deposited evenly over the retort, and the scoops made ready for another charge.

The "discharger" is a carriage similar to the "charger." The two are placed at opposite ends of the car, and the meter between them. By an automatic device, three hoes or rakes are simultaneously thrust into three retorts, dropped until they rest on the retort bottoms, and then withdrawn, whereby the coke is removed and discharged on to the retort-house floor, or into coke barrows.

One tier of retorts may be charged, and the adjacent one discharged at the same and in a very brief time.

The "pendent railway" consists of two single parallel rails, 10 ft. apart—suspended from the retort-house roof, over the railroad before mentioned, and connected at the ends by semicircular rails, thus, together, forming an endless line, from which is suspended a series of coal buckets, attached to a flexible steel belt, by which they are separated, at uniform distances apart. The belt passes around horizontal drums, 10 ft. in diameter, and placed one at each end of and below the line, their vertical shafts being in the centre of the curved rails. One of these drums is an idler—the other, that at the receiving end, is in a tower outside of the retort house. In its periphery are two openings, diametrically opposite, which, by two inclined shutes, are connected with a fixed cylindrical hopper, or reservoir, for coal above. The buckets are vertical cylinders, with one half of the upper part cut away, so that when they are in contact with the drums their axial planes coincide with the periphery. The space between the buckets on the belt is equal to one half the circumference of the drums.

When this apparatus is in motion, the buckets pass along the "pendent" railway—then openings are brought successively in contact with the openings of the drums, so that, the coal conveyed by the inclined shutes from the reservoir, drops through them—the quantity being regulated by valves in the shutes, worked automatically.

The buckets have hinged bottoms to drop downward, and are opened when passing over the "coal pocket" on the car, at the will of the operator, by releasing a catch; they are mechanically closed just before reaching the drum, where they are filled.

The coal in the yard, after passing between sizing and mixing rolls, is lifted to the reservoir over the drum, by elevators, similar to those used at Messrs. Hecker's flouring mills in New York.

The several parts of this apparatus can be worked independently, and thereby accommodated to the varying demands likely to be made upon it.

IRON AND STEEL NOTES.

IMPROVEMENTS IN THE "OPEN HEARTH PROCESS" OF MAKING STEEL.—Mr. B. B. Healey, of the Elba Steel Works, Swansea, has recently devised some important modifications of the "Open Hearth Process" of making steel, for the application of which works and very complete plant have been erected, and are now about to get into operation on a manufacturing scale. Two papers have been read on the subject by Mr. Healey to the Institution of Engineers in Scotland, and the following is a short summary of the descriptions contained in them: –

The furnaces are built in line with their tapping pits in the usual way, each furnace being provided with an hydraulic lift for the ladle carriage, and with a turn-table in front of the ingot moulds. To each pair of furnaces there is a two-ton hydraulic crane.

The ingots are cast in groups, the metal being conducted by means of feeders or "gits," and hollow or perforated bricks to the bottoms of the moulds, by which arrangement the ingots are cast solid, and by this mode of casting the weight of the "gits" made does not exceed the waste or loss in heating ingots for hammering, and even the greater portion of them are available for small merchant bars.

Great simplicity is displayed by Mr. Healey in the construction of the details of the lifts, turn-tables, ladles and crane, all of which are strong and effective. The hydraulic appliances are found extremely handy, both for regular work and for clearing the pits of "sculls" and slags.

In front of the furnaces there is a line of rails, which, with the ladle lifts, connects the line of furnaces. This arrangement may almost be regarded as indispensable, inasmuch as it is a source of great economy in itself. When the casting is going on, the ladle is above the floor line, the taps of the moulds being about level with the floor, and the comparative coolness of the casting shops which results from this arrangement is very agreeable to the workmen.

The furnaces are provided with an ingenious arrangement of continuous regenerators, and are supplied with gas which is produced in generators outside the casting shops, and conveyed to the furnaces by means of underground flues. Each furnace has a separate chimney and a separate nest of gas generators, and is thus found to work in a more regular manner than when several furnaces are connected with one chimney. By Mr. Healey's modification of the Siemens heat regenerative system, heat is restored to the furnace by means of regenerative tubes, which are built in a pair of chambers, the surplus heat passing continuously

through the tubes to the chimney, and the combustible gas and the air passing outside the tubes, so that by impinging in succession upon several tiers of them they may become heated as they approach the furnace.

The charges used at present at the Elba Steel Works are made up of Bessemer pig iron, wrought iron scraps, steel scraps, and Elba ore, the total loss in conversion being about five per cent. on the gross weight of metal charged into the furnace. In the steel resulting from the treatment of such a mixture there is usually from 0.35 to 0.45 per cent. of combined carbon, but other qualities are sometimes produced, which are used for tools of various kinds.

Successful experiments have been made by Mr. Healey to reduce the iron ore direct to steel, but at present this process is not in operation.

THE English papers are just now commenting with a good deal of feeling upon the fact that an English firm have ordered 1,000 tons of iron from Pennsylvania, and that steel railway axles cost £3 a ton less in the United States than in England. A correspondent of the "Ironmonger" reports that the chain trade of South Staffordshire with this country has almost ceased. "At this period of the year," he says, "we have usually been doing a great business in the lighter goods with the United States and Canada, and South America. The quotations have, however, lately so greatly advanced that nothing is now being done. It has not been an unusual circumstance for an order to the extent of 5,000 dozen to reach one of the merchant firms of Wolverhampton, but that firm is now getting scarcely an order, customers' communications intimating that the chains can be got in America at under the quotations of English makers. The high prices which have been necessitated in the past two years by the advances iron have greatly stimulated the industry in the United States, and team and draw chains and haimes are now being produced in immense quantities in St. Louis. The rise in these goods in this country, as compared with the quotations a little over two years ago, is from 100 to 130 per cent." Other proofs of our increasing ability to supply our own wants are mentioned, and the "Ironmonger," editorially, says: "In iron *per se* the successful competition of the American manufacturers is even more conspicuous, and that which has often been mentioned as an altogether improbable event seems likely to occur. We have information to the effect that one of the firms in the heart of South Staffordshire who use large quantities of strip iron are at this moment making arrangements to obtain from the mills of Pennsylvania no less a quantity than 1,000 tons of strip to be brought across the Atlantic, and to be used within sight and sound of the mills and forges whence at one time the Americans could alone obtain their iron. If this be so, the days of Macaulay's New Zealander upon London Bridge would, in the matter of the supreme sovereignty of the British iron trade, be nearer at hand than most people are disposed to imagine." On the other hand, the English are learning from us to diminish the size of some of their unwieldy tools, and they are copying our better models. They are making American axes and putting American handles to them, and report that in Australia the English article is not only cheaper but of better quality. According to their accounts, we are certain to lose the Australian trade in axes—the supply of which is said to be at present the most active and profitable branch of the edge tool manufacture in Sheffield. —*Engineering and Mining Journal.*

RAILWAY NOTES.

CENTRAL ASIATIC RAILWAY.—The latest proposal made with the view of facilitating our intercourse with Central Asia is that of M. de Lesseps, who has just put forward the idea of constructing a great Central Asiatic Railway from Orenburg to Samarcand, Bokhara, and Peshawur, which would complete the line of railway from Calais to Calcutta.

After the splendid success of M. de Lesseps with the Suez Canal, English engineers rather hesitate to say much against any project put forward by him, but still little encouragement has yet been given—at least in England—to the "Central Asiatic Railway." Perhaps political considerations alone are sufficient to prevent the accomplishment of the scheme; but, apart from these, it seems very questionable whether such a railway would really answer. According to a paper read at the last meeting of the Austrian Geographical Society by Colonel von Stubendorff, of the Russian army, the line would pass through Aralsk, the valley of the Sir Darya, Taschkend, and the Gates of Tamerlane, as any other route would be impracticable. From Samarcand to Peshawur the line would necessarily go through the Bamyan Pass and Cabul. The Colonel further stated that it was now pretty certain from the researches of Colonel Sbernitzky that the old bed of the Oxus extends eastward from Krasnovodsk in the direction of Bokhara, and that the construction of a line of railway along this dry river-bed from the Caspian to Bokhara and Samarcand would be comparatively easy. Such a railway would be in direct communication with Europe by means of the line of steamers from Krasnovodsk to Baku and the railway from Baku to Poti and Odessa. So far as the first portion, up to Samarcand, is concerned, there merely remains the question whether sufficient traffic could be obtained to repay the cost of construction, or, if not, whether the Russian Government would care to keep up the railway for State purposes and as a military road. When the Hindoo Koosh is reached, as has already been pointed out in an article on this subject by "Iron," the engineering difficulties would be so tremendous, and the cost of overcoming them so great, that it is difficult to conceive how the first cost of construction could be repaid. Then, again, the traffic on this second part of the line, except the through traffic from Europe to India, would be inconsiderable, on account of the nature of the districts traversed, and it is certain that the amount derived from the conveyance of goods and passengers over the whole line from one end to the other, would be utterly inadequate for the support of the railway without the aid of considerable local traffic, much more than can reasonably be expected. Doubtless, as the trade and resources of the vast countries through which the route would lie became more developed, such local traffic would gradually

arise, but it would certainly be very long before anything like a return from such sources could be expected.

So far as can be seen at present, therefore, it does not appear as if the project of M. de Lesseps offered any advantages, at least with regard to England, over the older scheme of a railway direct through Turkey, down the Euphrates valley, and along the coast line to Kurrachee and Bombay*, while it has, as compared with it, many serious drawbacks. Such a line would be more direct, shorter, and more easy of construction; and, if it would not help the important question of opening up this vast district of Central Asia, it would, as a highway to the East, be more convenient and direct than the new route.

A Series of experiments were lately made at one of the Sheffield foundries with an improved steel car wheel, which gave most satisfactory results. In the construction of this wheel an ordinary rolled crucible of Bessemer steel, iron, or other tyre, is heated as hot as possible without burning, in a suitable furnace, and then deposited in a casting box, the nave being first placed in the centre and moulded thereto in the ordinary way. Molten crucible steel or iron is then poured therein, whereby it becomes united together in one solid or hollow homogeneous weldless wheel, thus obtaining a combined wheel of great strength, elasticity and tenacity, free from the defects and liability to breakage of those in ordinary use; the wheel is afterward annealed, if required.

For wheels of a similar construction to those at present in ordinary use upon railways, the tyre is first suitably heated and deposited in the casting box, and then the nave placed in the centre. Pieces of crucible or Bessemer steel, or wrought iron, of the necessary thickness, cut into suitable lengths to form the arms or spokes, are arranged around, and retained in their position by moulding in the usual way. Molten steel, iron, or other metal, is then poured in until they become united into and form one solid homogeneous weldless steel or metal wheel.

These wheels are said to be peculiarly free from jarring and concussion, as well as more economical than ordinary wheels, and not so liable to sudden expansion or contraction; the absence of complicated tyre fastenings is also an advantageous feature.

ENGINEERING STRUCTURES.

The Mersey Tunnel Scheme.—This important engineering work is progressing slowly but surely, and in the course of time Liverpool and Birkenhead will be connected by other means than the penny steamboat. The progress of the work thus far may be thus described: A working shaft 36¾ ft. long and 8 ft. wide has been sunk to the required depth of the tunnel. This shaft passed through a portion of an old quarry, but its lower half is cut in new red sandstone of a very hard description. The depth of the shaft keeps the crown of the heading, now being cut, about 80 ft. below the Mersey high-water level. The formation of the tunnel will allow of the junction being effected with the Birkenhead and Chester Railway. Already over 200 ft. of the tunnel have been dug, two gangs of miners being constantly at work. The fresh water in the shaft accumulates at the rate of 5,000 gallons per hour; and when the sub-river tunnel is completed the drainage will be effected by a drift way, with a slight fall from the middle of the river to the shafts on either side. The tunnel from the Birkenhead station to the shaft near the Ferry will contain two lines of rails, but under the river there are to be two single tunnels, with one line of rails in each. The advantage of this will be found in the better means of ventilation when the traffic in each tunnel tends in the same direction, and further in the fact that there will be a greater space between the crown of the tunnel arch and the river's bed than would otherwise be obtainable. Each of these tunnels will be a mile long, from shaft to shaft, and three-quarters of a mile actually under the river; they will be 15 ft. high, and at an average depth of 30 ft. below the river's bed. The greatest depth of the river is about 67 ft. at low water, and 95 ft. at high water, and at no point of the tunnel will there be less than 20 ft. of solid rock between it and the river's bed. The engineers, Messrs. J. Brunlees and Mr. C. D. Fox, report no fault whatever in the projected course of the tunnel under the river, the rocky bed of which is bare for two-thirds of the length, and covered with clay and sand on the Liverpool side. In order to prevent the percolation of river water, the tunnel will be lined with Staffordshire blue bricks set in Portland cement; and while the works are in progress strong pumping power will be kept up on both sides of the river. The gradients in the tunnels will be about 1 in 40. Though the actual tunnelling under the river has not commenced, contracts are to be at once carried out by the Diamond Boring Machine Company, whereby a heading 9 ft. high by 9 ft. wide is to be driven under the river some 1,300 yards within the next twelve months; and both sub-river tunnels are to be completed and ready for traffic in about double that period. This boring apparatus is said to be excavating at least 16 yards per week under the limestone on Clifton Downs, Bristol, and the absence of faults in the sandstone under the Mersey presents a favorable opportunity for the machine being efficiently worked.

Baltimore and Potomac Tunnel.—The Baltimore "Sun" gives the following resumé of the present condition of the work:

"The tunnel, running through a portion of the western section of the city, is upon the verge of completion. It was begun May, 1871, and the city ordinance giving the Balt. & Pot. R. Co. the right to construct the tunnel under the beds of certain streets requires the portion on those streets to be finished during the present month. This requirement will be complied with. The tracklaying is now proceeding, about half a mile of the tunnel being already laid with double tracks of steel rails and stone ballasting. The tunnel is made with two open cuts, one of 200 feet and the other of 345 ft. Exclusive of the open cuts, the tunnel is 6,448 ft. long, and with the open cuts 7,593 ft. It connects the B. &. P. R. with the N. Cent. R. at North avenue bridge over Jones'

* See Mr. Hyde Clarke's paper on the subject in the "Journal" for Nov. 24, 1871.

Falls, the portal of the tunnel being at the western abutment of the bridge. It then follows the line of Wilson from Oliver to John street. The first open cut (between Oliver and John streets) will be kept open for ventilation and light. From John street the line follows Wilson street to Pennsylvania avenue, where it curves to the right into Winchester street. Here is the other open cut; it will be kept open for the reasons before stated. and also for a depot, which will be located here fronting on Pennsylvania avenue. Passengers will descend by stairs from the depot to the track. Thence the tunnel runs, still under the bed of Winchester to Gilmor street, where it ends, connecting with its road running into the open country. The distance between Bolton and John streets, about 1,100 feet, is tunnel proper; that is, it was carried through by drifts wholly under ground. The other part of the tunnel was worked by making an open cut, then arching the tunnel, covering it over and restoring the grade of the street. The most serious difficulty arose from the streets being built up with houses on each side. To prevent the earth from caving in and causing the houses adjacent thereto to crack and settle, it was necessary to make the sides of the cut vertical, and to support them with heavy timber. The tunnel is constructed so as to almost insure stability and safety. The masonry of the abutments all along the tunnel rests on solid rock, clean sand or gravel, with haunch backing stone all the way up the sides of the cut. Some springs were struck, but as the tunnel is enfirely down hill, the water has simply been turned and drained into the falls. The arch is turned with five rings of brick and well backed with rubble masonry. The side walls are of massive masonry, of Cockeysville marble, rock faced, but dressed at beds and joints.

The cost of the tunnel, it is estimated, will be about $2,000,000. It is expected the cars will be running through about June 1. The West. Md. R. connects with the tunnel at Fulton avenue.

KUILENBORG (HOLLAND) BRIDGE.—*An Ingenious Resource.*— During the construction of the bridge at Kuilenborg, Holland, says the "Chronique de l'Industrie," one of the principal traverses, some 465 ft. in length, was placed about one inch too far on the piles. This error was rectified in a very ingenious manner. The expansion of the mass of metal was exactly .0394 in. per Fahrenheit degree. At the locality of the work the difference between the temperature of the atmosphere by day and by night was 25 deg. Fahr. In the morning the too far advanced end of the traverse was securely bolted down, when during the day the heat of the sun expanded the metal so that the free extremity advanced .985 of an inch. Then at night the latter end was fastened and the contraction caused a like movement of the opposite free extremity. This operation, twice repeated, brought the traverse into its proper position.

ORDNANCE AND NAVAL.

TEAK FOR SHIPBUILDING PURPOSES.—The almost universal adoption of iron as a material for shipbuilding, and more especially the introduction of armor-plating, have had an enormous effect on the consumption of teak, on account of the peculiar properties which it possesses, and which render it so suited for employment in combination with this metal. Till within the last few years, almost the whole of the teak consumed in Europe came to us from Rangoon and Moulmein, in Burmah, in which country whole forests have been devastated without much regard to the future, in order to meet the ever-increasing demand.

The threatened exhaustion of the Burmese forests has caused consumers to turn their eyes in other directions for a supply of this wood, and in a recent article in the "Revue Maritime," M. Bernier Fontaine, a naval engineer at Toulon, recommends importers to direct their attention to Siam, in which kingdom and its dependencies it appears that teak exists in great abundance; to such an extent, in fact, that the English in Burmah are becoming accustomed to organize expeditions for obtaining their supplies of the wood from the Siamese forests. It is largely used in the country itself, being employed there for every kind of woodwork, and also to a great extent for shipbuilding purposes. The principal forests, M. Fontaine tells us, are situated on the chain of mountains separating the basins of the Saiweer and Mei-Nam, about 500 miles from Bangkok. They are the property of the Siamese Government, and before anyone can proceed to fell the trees in them, it is necessary to obtain a letter from the King of Siam, or one of the chief mandarins, to the governor of the province in which the forests are situated. The latter arranges in what districts the trees shall be felled, and the tax to be paid for the privilege. This is, in general, about 4 rupees a tree, no matter what its size, in addition to which there are the wages of the woodcutters, the cost of transporting the trees to the nearest watercourse, generally performed by elephants, the forming of the wood into rafts, and the floating of the rafts by the river Mei-Nam to Bangkok. The journey from Bangkok to the forests is made in sailing vessels, during the dry season (November to February), and usually takes about a month; but owing to the rapidity of the current at this period of the year, the return voyage lasts only six or eight days.

The trees, when cut, are generally from 30 ft. to 35 ft. in length and 12 in. to 18 in. square. Having been lopped and barked in the forest, they are transported to the nearest affluent of the Mei-Nam, where they are formed into rafts consisting of several hundred trees, bound together by reeds. Owing to the fact that these rafts can only descend the river at the end of the wet season, when the waters are at an abnormal height, two years generally elapse between the time that the trees are marked for felling and their arrival at Bangkok. The first dry season is devoted to the choice of the trees and to felling and trimming them; the following wet season to their conveyance to the different watercourses, and the second dry season to the formation of the rafts. Arrived at Bangkok they are squared by hand by Siamese workmen, and the European merchants generally make their purchases at the native saw-mills, though they will sometimes buy the rafts entire. In this case, however, the only guarantee for the quality of the wood is the character of the sellers, who are not to be too much relied upon, and who are exceedingly skilful in concealing the flaws to which teak is especially subject.

This important trade, it appears, was long a monopoly in the hands of the Chinese, but of late years the forests have been visited by Europeans, some of whom have undertaken the felling of trees on their own account. In both cases, however, the woodcutters employed are the native inhabitants of the forest districts.

But little of the Siamese teak reaches Europe, at least, by way of Bangkok, the greater portion going to Singapore, Hong Konk, and Bombay. The wood is said by M. Fontaine to be generally of very good quality and free from clefts or "shakes." There are three varieties—black, yellow, and white—supposed to depend upon the age at which the tree is felled: the first two are mostly to be preferred. It is estimated that the wood could be delivered in a port of the United Kingdom at about £14 a load, and would fetch there £15 10s.; but should the trade once become fairly delivered, there is little doubt that the expenses of transport, etc., might be considerably reduced.—*Iron.*

NEW GERMAN MONSTER GUN.—Our 35-ton gun, the much-talked of Woolwich infant, has been excelled by a new German monster gun, now exhibiting at Vienna, from the works of Herr Krupp. This new 12-in. gun fires a solid ball weighing 700 lbs. with a charge of 130 lbs. prismatic powder, the English gun propelling a projectile weighing only 600 lbs. In the experiments with the latter, according to the military correspondent of the "Cologne Gazette," the results obtained were far from satisfactory; 230 rounds fired from the German gun, five of them with the maximum charge, on the contrary, did not cause the slightest perceptible injury either to the barrel or to the carriage. The barrel of the gun is about 22 ft. in length, and weighs a little over 33 tons. It has 72 parallel grooves, with a length of bore of about 19 ft. The carriage weighs a little over 19 tons, and the total weight of gun and carriage reaches therefore nearly 53 tons. The steel shell fired from this gun with a charge of 132 lbs. of powder, weighs a little over 650 lbs. Its initial velocity amounts to 1,590 ft. Loading is effected by means of a crane fixed on the barrel, and in a very short time. The projectile is calculated to make a clean hole through a 15-in. iron plate at a distance of 1,000 yards.

Besides this monster gun the same firm exhibits at Vienna a mass of cast steel block weighing 105,000 lbs., shaped into an octagonal form by means of the 50-ton steam hammer, and intended for a 14-in. gun (1,100 pounder), which latter will consequently exceed considerably the 50-ton gun projected in England.

A NEW method of discharging fire-arms, dispensing with gun locks and all similar machinery, has been invented by an American Professor. He fits up a small galvanic battery within the handle of the gun or pistol, or employs alternatively a Leyden jar and rubber to generate a current of electricity, which, in either case, passes by a wire to the cartridge. An arrangement is added whereby, on pressing a pin with the finger, a spark enters the cartridge and fires the powder. It only remains for him to so far improve his improved gun as to propel a ball without the cumbrous intervention of gunpowder at all.

BOOK NOTICES.

ELECTRICITY. By ROBT. M. FERGUSON, Ph.D., etc. W. & R. Chambers. For sale by Van Nostrand.

Next to their "Chemistry" and "Mathematical Tables," Dr. Ferguson's book on "Electricity" is the best of that series of works by which the Messrs. Chambers affirmed their position as the greatest practical promoters of technical education in the kingdom—and we know no higher praise.

The Science and Art Department of the Education Office rightly enough makes "electricity and magnetism" a special subject; and the educational interest in the matter is shown by the fact that this year the number of papers sent in to South Kensington has increased from 4,000 last year to more than 6,300 in last May That department, according to its prospectus, makes Dr. Ferguson's work the sole text-book for examinations; and this fact is somewhat decisive as to the merits of his "Electricity."

The author enjoys peculiar facilities for writing such a volume. His education in Germany, and his intimate acquaintance with Continental scientific literature, specially fit him for giving us—as he has done—a clear view of the most recent theories and experiments which have established themselves in connection with this particular department of science. Another advantage possessed by the author is, that he has for many years occupied one of the most distinguished positions as a teacher of science in Edinburgh.

The result is a perfect manual of practical and theoretical science, so far as any book can be so, which aims at only being introductory to the mathematical study of the laws of electricity and magnetism.

THE ELEMENTS OF EUCLID: WITH MANY ADDITIONAL PROPOSITIONS AND EXPLANATORY NOTES: TO WHICH IS PREFIXED AN INTRODUCTORY ESSAY ON LOGIC. By HENRY LAW, C. E. London, 1873. For sale by Van Nostrand.

Mr. Henry Law's version of "Euclid" forms one of the excellent educational works known as Weale's Rudimentary Series. Many attempts—rendered necessary by the natural stupidity of the human race—have been made to produce a "royal road to mathematics," or "Euclid made Easy." Mr. Law has struggled manfully with the difficulties that hedge in the subject which of all others imposes upon the student the often-talked-of but rarely performed operation known as "thinking." To the learner who will really and honestly do his best to "think out" and understand the subject that he is studying, no more delightful author than Euclid ever existed. But unhappily beings exist so singularly constituted that they are driven to learn the propositions of Euclid by rote, and the difficulty is how to deal with these peculiar creatures, who make mere memory perform the functions of reason. So far as explanation and illustration can be pushed, Mr. Law has done his best to smooth the road beset by torturing angles. In the second book we find that, in accordance with prevailing custom, algebraic demonstrations are appended to the purely geometrical solutions of the Greek mathematician. If the object be mainly to simplify the subject, we see no reason why, in many of the pro-

positions—simple arithmetic should not be called in to aid the teacher. We have tried this plan on pupils of peculiar density, with very fair success. A little care in the selection of the figures will bring out the result clearly enough. Of the advantage of the introductory essay on Logic, we venture to entertain some doubts, and question much whether the student who fails to apprehend the clearness of a geometrical demonstration will be materially assisted by a dissertation on the syllogism. A classified index is an excellent addition to "Euclid's Elements," and the extreme cheapness of the "Rudimentary Series' cannot fail to recommend it to the public.

TREATISE ON THE STRENGTH OF BRIDGES AND ROOFS, WITH PRACTICAL EXAMPLES FOR THE USE OF ENGINEERS AND STUDENTS. By SAMUEL H. SHREVE, A. M., C. E. 1 volume, 8vo., 346 pages. New York, published by D. Van Nostrand.

Mr. Shreve has produced a book which is, perhaps, more satisfactory to the majority of practical engineers than any previous work upon the strains of framed structures. He begins with the simplest principles of the subject, and by an inductive course of algebraic reasoning carries the reader through most of the different forms of built beams, giving the methods of computing the strains upon the several members, with examples worked out for illustration There is nothing in the whole work but can he readily understood by the ordinary professional reader, and nothing is taken for granted except the ordinary elementary principles of mechanics.

He has adopted an almost entirely original method of treating the subject, which possesses the great merit of being applicable to all forms of trusses. He is, indeed, the only writer who has pursued the same systematic course of reasoning through all the different forms of trusses of which he treats. Rankine's method of sections, it is true, is applicable to every form of framing; but as given by the author and applied by Unwin and others it is somewhat complex and unintelligible, and is rarely understood by practical engineers, who have no time to waste in trying to study out what an author means. At the present day, in order to make a book valuable it must be inductive in its reasoning and as simple and concise in its mathematics as the subject will admit of. Very beautiful demonstrations in the higher mathematics are oftentimes wasted, because those who can comprehend them are generally too much occupied to devote themselves to such reading. It also very often happens that the most elaborate trains of reasoning by the calculus and higher mathematics are made upon insufficient premises and erroneous assumptions, which lead to inaccurate results not readily perceptible to the general reader.

This is particularly the case with those authors who reason analytically upon the strains to which a beam is subjected when loaded, and deduce therefrom curves of strains representing the forces acting upon the different members of a truss.

The method adopted by Mr. Shreve of regarding the strains upon the several members of a truss as a mechanical problem in which the actual existing forces under certain conditions are to be considered, is undoubtedly the best. It is the one generally preferred by English and American engineers, and is theoretically the most correct.

Not the least of the advantages of Mr. Shreve's book is the admirable manner in which his meaning is expressed, and the simple nomenclature adopted. He is always so clear as never to leave the reader in doubt, and avoids the use of such meaningless terms as "shearing strain" or "shearing force," for the diagonally transmitted force along the truss, which has become so common among English writers. That it is not a shearing force is very easily shown.

On the whole, Mr. Shreve has produced a book which is the simplest, clearest, and at the same time the most systematic and with the best mathematical reasoning of any work upon the same subject in the language.

Among the refinements of the subject introduced by Mr. Shreve is the consideration of the counter-strain produced by the partial loading of the next panel whenever one panel becomes fully loaded by a progressive load. Although this and likewise the stiffness of the cords and rigidity of the joints of a truss have the effect to diminish the maximum computed strain upon any one brace from a rolling load, they will rarely be taken into consideration by the practical designer of bridges; as the differences are on the safe side, are somewhat indeterminate, and are generally within the difference of opinion regarding the value of the factor of safety and the probable strength of the materials used. It is well, however, in an elementary work to discuss all of the above-named points, and ascertain their ordinary effects upon the strength of the structure.

It is to be sincerely hoped that Mr. Shreve will give us another volume treating upon the forms of framing which he has omitted, and the practical considerations which should govern the proportions and construction of bridges and roofs—such as the best systems of riveting and joining plates, the best form and proportions for links and pins, and, in fact, all such details as are usually acquired by practice and experience in the engineering profession.—*Railroad Gazette.*

GEOLOGICAL SURVEY OF CANADA. REPORT OF PROGRESS. By ALFRED R. C. SELWYN, F. G. S., Director. Montreal: Dawson Brothers.

An important addition to our knowledge of the geology of the continent is afforded by the present report.

The separate reports which form the present volume are: The report on British Columbia—On the Coal Fields of Vancouver Island—on the country between Lake Superior and the Albany River—On the country between Lake St. John and Lake Mistassini—On the counties of Leeds, Frontenac and Lanark, and on the gold of Marmora—On investigations in New Brunswick and on Mining and Mineral Statistics.

THE GEOLOGY OF THE STARS. By Prof. A. WINCHELL. Boston: Estes & Lauriat. For sale by Van Nostrand.

This little essay forms No. 7 of "Half Hour Recreations in Science." The author is well known to the scientific world, and his name is a sufficient guaranty that the speculations in re-

gard to the structure of far-off worlds are at least rational when viewed in the light of recent discoveries. The young reader may feel assured that he is in safe hands. No pleasanter way of summing up for the general reader the late astronomical discoveries could be devised, than by showing the bearing of such advanced knowledge on the theories which are constructed and rendered tenable by these discoveries; and no one of our scientists is so capable of thus presenting modern science as Prof. Winchell.

SANITARY ENGINEERING. A Guide to the Construction of Works of Sewerage and House Drainage. By BALDWIN LATHAM, C. E. London. For sale by Van Nostrand.

The title of this book sufficiently explains the author's plan and what it properly includes. It is sufficient therefore to say that the book seems complete in all respects.

Engineers have heretofore in designing such works relied chiefly upon the plans and formulas collated for brief reports of works yet in progress, and while some of the methods were to a certain extent yet untried, a book setting forth successful plans has long been a desirable addition to technical literature. The present work seems all that could be asked for. The illustrations are excellent and very numerous.

A COMPENDIOUS MANUAL OF QUALITATIVE CHEMICAL ANALYSIS. By CHARLES W. ELIOT and FRANK H. STORER. Revised with the co-operation of the authors. By WM. RIPLEY NICHOLS, Professor of General Chemistry in the Massachusetts Institute of Technology. New York: D. Van Nostrand.

The simplicity and efficiency of the system of qualitative analysis so carefully described by Fresenius, has led to his manual being made the basis of all the best text-books on the subject which have since been published, and it would be difficult to say anything in higher commendation of a work of this class than that in it Fresenius is closely followed, whilst the instruction is given in language readily intelligible to the English student. With the advantage of a good memory, and a thoroughly competent teacher, the bare tables we were accustomed to some seventy years ago, as "Giessen Outlines of Analysis," would probably be ample, but it is indisputable that there are many students who, unless the text-book run very closely to the explanations given by the Professor, make comparatively little progress; and that facility to refresh one's memory as to the statements heard in the lecture-room is advantageous to all. The compendium of Messrs. Eliot and Storer, the new edition of which, by Prof. Wm. Ripley Nichols, is designed to form an introduction to text-books of this class, is certainly one of the most lucidly arranged that has been issued. Being intended more especially for the general student, reference to comparatively unknown substances—elements which occur so rarely, and even then in such minute quantities that unless for purely scientific investigation they would be neglected by the professional analyst—is very properly omitted, for such omissions do not lessen the value of the work, and, at the same time, permit of its being much simplified.

In the volume under consideration there is given so complete an outline of inorganic analysis that few except professional chemists will require to know more than can be taught with the compendium alone as a text-book, whilst to the student proposing to devote himself chiefly to chemistry it will prove a very valuable collection of facts necessary to be remembered, and around which the more minute details can be readily grouped without needlessly overburdening the memory. It is, of course, assumed that the student will have already some knowledge of general chemistry when he commences the study of qualitative analysis, and the first chapter is, therefore, appropriated to an example of the separation of two elements and to the explanation of the principle upon which the twenty-four metallic elements most commonly met with are divided into seven classes. A separate chapter is then devoted to each class, so that the chlorides insoluble in water and acids (lead, silver, mercury) stand alone; then come in succession the sulphides insoluble in water, dilute acids, and alkalies; the sulphides which differ from these in being soluble in alkaline solutions; the hydrates insoluble in water, ammonia water, and solutions of ammonium salts; the sulphides insoluble in water, and in saline or alkaline solutions; the carbonates insoluble in water, ammonia water, and saline solutions; and the three metallic elements (magnesium, sodium, and potassium) which remain in solution after the application of all these tests. These are followed by others on the general and special tests respectively for the non-metallic elements. The sound part of the volume, divided into three chapters, describes the treatment of substances of unknown composition; whilst, by way of appendix, there is a careful statement of the re-agents and apparatus used in the course.

From what has already been said, it will be understood that in books of this description the superiority or otherwise must be judged of by looking at details, and in these the compendium has much to recommend it, as an example of which is the hint with reference to the labelling of solutions put aside for subsequent treatment. When a filtrate has been obtained the direction is given "Label this filtrate," etc., and to this the invaluable note is appended, that the student should at once make it a rule to label every filtrate or precipitate which he has occasion to set aside even for a few moments. A bit of paper large enough to carry a descriptive symbol or abbreviation should be attached to the vessel which contains the liquid or precipitate. Paper gummed on the back, or the small labels which are sold already gummed, are convenient for this use. This habit once acquired will enable the student to carry on simultaneously without error or confusion several operations. He may be throwing down one precipitate, washing another, filtering a third, and dissolving a fourth at the same time, and the four processes may belong to as many different stages of the analysis. There will be no danger of error if labels are faithfully used, and a great deal of time will be saved. The unaided memory is incapable of doing such work with that full certainty admitting of no suspicion or after qualms of doubt, which is alone satisfying, or indeed admissible, in scientific research. Hints of this character occur in various parts of the book; and the tabular views of the

determinative tests (of the character of those used in Normandy's large works), will add to the facility with which the book can be used.

The fact of the volume having already passed through several large editions is of itself a guarantee that it is not wanting in utility or in reliability, and although the information given is necessarily similar to that met with in other works of the kind, the manner in which it is given is well calculated to impress the facts which have to be remembered upon the attention of the learner, whilst the limits and suggestions, which are so complete as to extend even to the explanation of the best methods of removing a bottle-stopper, cleaning a mortar, and so on, cannot fail to make the student who has the book for his guide a clean and ready manipulator, and one that can at all times rely upon results which will be creditable to himself and satisfactory to those for whom the analysis is made.—*London Mining Journal.*

MISCELLANEOUS.

THE MORTAR OF THE GREAT PYRAMID.—At the last meeting of the Chemical Section of the Philosophical Society of Glasgow, the President, Dr. Wallace, F. R. S. E., read a paper in which he gave a number of interesting details regarding the mortar employed in building the Great Pyramid, and incidentally referred to the composition of some mortars that he analyzed a few years ago, including two from the interior and exterior of the Great Pyramid, two specimens of very ancient Phœnician mortar from the Island of Cyprus, two from ruins at Athens, and from Rome and other places in Italy. It was most interesting to observe the remarkable differences between the mortars of the various ancient peoples. By going to Baalbec and other ruined cities of Turkey in Asia, buildings might be found constructed of immense blocks of stone jointed with such excessive nicety that even the blade of a penknife could not be pushed between them, but without a vestige of mortar. In the structures of the ancient Egyptians, on the other hand, taking the Great Pyramid as an example, mortar was freely employed, but consisting almost entirely of gypsum or sulphate of lime. A specimen was examined from an ancient Phœnician temple, the highest stone of which was, a few years ago, 5 ft. below the level of the ground at the time the specimen was taken. It was something like that found in some of the baronial castles in this country, and was like a piece of solid rock. The gentleman who brought it home supposed it to be the very oldest mortar in existence. If it were, so, Dr. Wallace said that it was most remarkable, inasmuch as it was as perfect in constitution as it could possibly be, having been made, evidently, of burnt lime, fine sand, coarse sand, and gravel. It might be called concrete, rather than mortar. At any rate, one thing was certain—namely, that the lime in it had become completely carbonated; and another specimen of the same age exhibited the same phenomenon, thus satisfactorily settling a point which was long in dispute.

The ancient Greek mortars from ruins in the vicinity of Athens were also very perfect, but contained more lime than that from Cyprus, and no gravel. The mortars from various ruined buildings in Herculaneum, Rome and its neighborhood, appeared to have been made from burnt lime and puzzuolana, or what is called by geologists volcanic ash. Dr. Wallace stated that he had had some correspondence with Professor Piazzi Smyth regarding the mortar of the Great Pyramid, some portion of which he read, and he gave the following analysis of a specimen which he had recently examined:

Hydrated sulphate of lime	92 83
Carbonate of lime	4.63
Carbonate of magnesia	1 66
Alumina and traces of oxide of iron	.24
Silicon	.88
Water (hygroscopic)	.07
	100.31

The following are analyses of two specimens examined a few years ago:

Hydrated sulphate of lime	81.50	82.89
Carbonate of lime	9.47	9 80
Carbonate of magnesia	.59	.79
Oxide of iron	25	.21
Alumina	2 41	3 00
Silica	5.30	4.30
Water (hygroscopic)	....	....
	99 52	100.99

In reply to a question, Dr. Wallace stated that he believed the sulphate of lime, which is abundant near the Pyramids, had been partly calcined to drive off the water of hydration in the mineral before being used in making the mortar. There was very little cohesiveness in the samples exhibited.

QUARRIES OF SISTIANA.—The stone used in the construction of the harbor of Trieste is obtained from the quarries of Sistiana, near that port. A million cubic metres of stone are required in five and a half years, and for such colossal blastings powder chambers are cut in the rock, which may be distant from its face one-half to two-thirds of the distance or depth from the upper surface, and which are large enough to contain one-third to one-half as many kilogrammes of powder as the quantity of rock to be blasted contains cubic metres; 800 kilog. of powder are considered necessary for one cubic metre of bulk. But in order to form such a chamber a shaft has to be driven near the point where it is to be formed; and thence, a shaft two metres long is sunk downwards, and the powder chamber formed at its lowest point. In this manner forty-six large mines, with charges of from 2,000 to 30,000 kilog., have been blasted in the quarries of Sistiana from the beginning of 1868. The average result was 2.02 cubic metres of useful material for every kilogramme of powder. It must, however, be noticed that the rock, a grayish white limestone, frequently and unexpectedly reveals great cavities, which greatly lessen the effect, and that considerable quantities of powder are requisite for reducing large masses of rock, when the principal mine was not sufficiently charged. For reducing large blocks, holes were bored by caustic holding as much as 300 kilog. For such blastings a hole is made in the usual way, with stone-borers 3 to 6 centim. wide, and 4 to 10 metres long; oil of vitriol is then continuously

introduced by means of hemp descending to the bottom of the hole, whereby the stone is dissolved. The hemp is in a small tube, which is enclosed in a larger one, through which the carbonic acid formed at the bottom of the hole flows back into the vessel whence the sulphuric acid descends. It is calculated that 100 kilog. of hydrochloric acid of 1.2 specific gravity and 40 per cent. of hydrochloric acid, in 18 hours make a hole large enough for from 10 to 12 kilogrammes of powder.

SAFETY VALVE AREAS.—The Board of Trade rule for area of safety valves allows one-half square inch for each square foot of grate surface with natural draught. The French law requires an area of $A = \frac{22.5}{P + 8.62}$, where A = area in square inches per square foot of grate, and P = the pressure as indicated by steam gauge. This is also adopted and recommended by the Committee of the Franklin Institute. The United States regulations, as applied to steam vessels, require twenty square inches area for each 500 sq. ft. of effective heating surface, or $A = \frac{H\ (\text{eff.})}{20}$.

AN English exchange publishes an account of a new artificial stone, now generally used in the Rhine country. The principal material for them is natural and artificial pumice-stone, viz., granulated blast furnace slags, mixed with ordinary slacked lime or hydraulic cement. The natural pumice-stone is the last product of the now extinct volcanoes of the Rhine in the environs of Coblenz, where enormous deposits of volcanic ashes are found a few feet below the surface, covering an elliptic area of about 36 English miles long and 20 miles wide. This bed of pumice stretches from Mayen to Westerburg, in Nassau; and from Boppard to Brohl it is intersected by the Rhine; it is known by the local name "Enger-sandstone," and is composed of thin horizontal stratifications of small pieces of pumice, varying in aggregate thickness from 2 ft. or 3 ft., to 20 ft. and 30 ft.; it is thickest in the basin of Neuwied, around the town of that name. In the iron district of Siegen, where the natural pumice is not found, granulated blast furnace slag or cinder is used instead. Here an uninterrupted stream of slag is run in a rapidly flowing stream of cold water, which carries the spongy bits of floating slag into a settling pit, whence they are shovelled out ready for use. The granulating of blast furnace cinder has of late become a very profitable undertaking, as it rids the works at once from a cumbrous burden and provides a considerable income besides. The manufacture of artificial stone from both materials, pumice and granulated slag, is the same, and very simple. Over a heap containing 6 to 8 cubic ft. of stuff, thin slacked lime is thrown with a shovel and mixed with it, until, pressed in the hand, it sticks loosely together. It is then filled in a cast-iron mould of the size of the brick, which is open at top and bottom, and rests on a table upon a piece of a thin deal board. By means of a kind of ladle and a flat hammer the mixture is rammed hard, until the mould is evenly filled; the moulder then lays a rectangular piece of sheet iron which is a little smaller than the brick, upon it, and by pressing both thumbs downwards at the same time, he disengages the brick, which remains upon the deal board, and is deposited with it upon a drying shelf. The mass, at first, but little coherent, becomes, after a fortnight, exceedingly hard, and will stand a considerable load before breaking np. Instead of common lime, hydraulic cement is used in exactly the same way, with the advange, however, that the bricks are ready for use almost immediately after their manufacture. For making pipes, chimney-pipes, troughs, and other objects, hydraulic cement is used exclusively, as it hardens much quicker, and gives a greater resistance to them. An exellent natural cement, the so-called "Trass," a kind of volcano tufa, is found at Brohl, close to the deposit of pumice, and is largely employed in the manufacture, as well as Rhenish Portland cement.

The London Society of Engineers have been investigating the merits of another kind of artificial stone, composed of sand, boulders and chemicals. The sand is dried by the application of heat to a piston or shaft, through which the sand percolates at the rate of one ton per hour; this drying of the sand at starting being necessary, in order to ascertain exactly the amount of effective force of the mixture employed. The boulders are obtained from the sea-beach and plunged into huge boilers, or digesters, filled with a solution of caustic soda, which, operated on by heat, gradually reduce the hard stones to a liquor resembling in consistency and color stationer's gum. It is said to contain 66 per cent. of silicate and 33 per cent. of soda. To get rid of the soluble properties of this liquid, and at the same time retain its cohesive properties, it is compounded with chloride of calcium, and being thus made cohesive and insoluble, it is poured into a mixing mill, along with sand, and presently sparkles with crystals. Tranferred to moulds, it is made to assume any pattern or form desired, and is then carefully placed in a bath, where its becoming hard is a question of only a few moments, and the results entirely of chemical affinity. The hardness of the composition was shown by the application of a hammer to a four-inch cube, which had been exposed to the atmosphere for three months, and which stood a pressure of 63 tons before it broke.

UPPER MISSISSIPPI IMPROVEMENTS.—The "Gate City" says that Maj. F. W. Farquhar has in charge the work in Minnesota river; survey of Red river from Morehead to Pembina; preservation of the Falls of St. Anthony; survey of the Galena river 12 miles; work at Duluth harbor and the Meeker's Island lock and dam; the territory having recently been made a new district. Col. Macomb has still charge of the Des Moines Rapids at Keokuk, Rock Island Rapids, and the Illinois river improvement. Major Amos Stickney has local charge of the improvement at K., and is a most efficient officer.

RAILWAY BRAKES IN BELGIUM.—Two of the Belgian Railway Companies have placed experimental trains at the disposal of inventors of brakes, which are considered to present advantages. The Great Central Belgian is about to try the well-known and widely-tried Westinghouse air-brake, and the Great Luxemburg Railway will, we believe, follow their example.